IMPLEMENTING A FRESHWATER SALMON HABITAT MONITORING PROGRAM IN THE SKEENA WATERSHED

By

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ABSTRACT

This project develops a framework for implementing a collaborative freshwater salmon habitat-monitoring program in the Skeena watershed. Its purpose is to help catalyze federal Wild Salmon Policy strategy 2 implementation and stimulate ecosystem based management and cumulative effects assessment by providing baseline status and trend salmon habitat monitoring data and analyses. Key components of the project include; identifying the need and support for a salmon habitat-monitoring program, recommending indicators, and outlining current habitat monitoring activities. The project also provides recommendations on governance and structure, participation, data collection, analyses and storage, monitoring prioritization and expansion, communications, management integration, and capacity requirements required for an effective program. There is support and value in developing a Skeena salmon habitat-monitoring program, and implementation can be achieved in a cost effective, practical, and sustainable manner using existing resources and by fostering multi-party monitoring.

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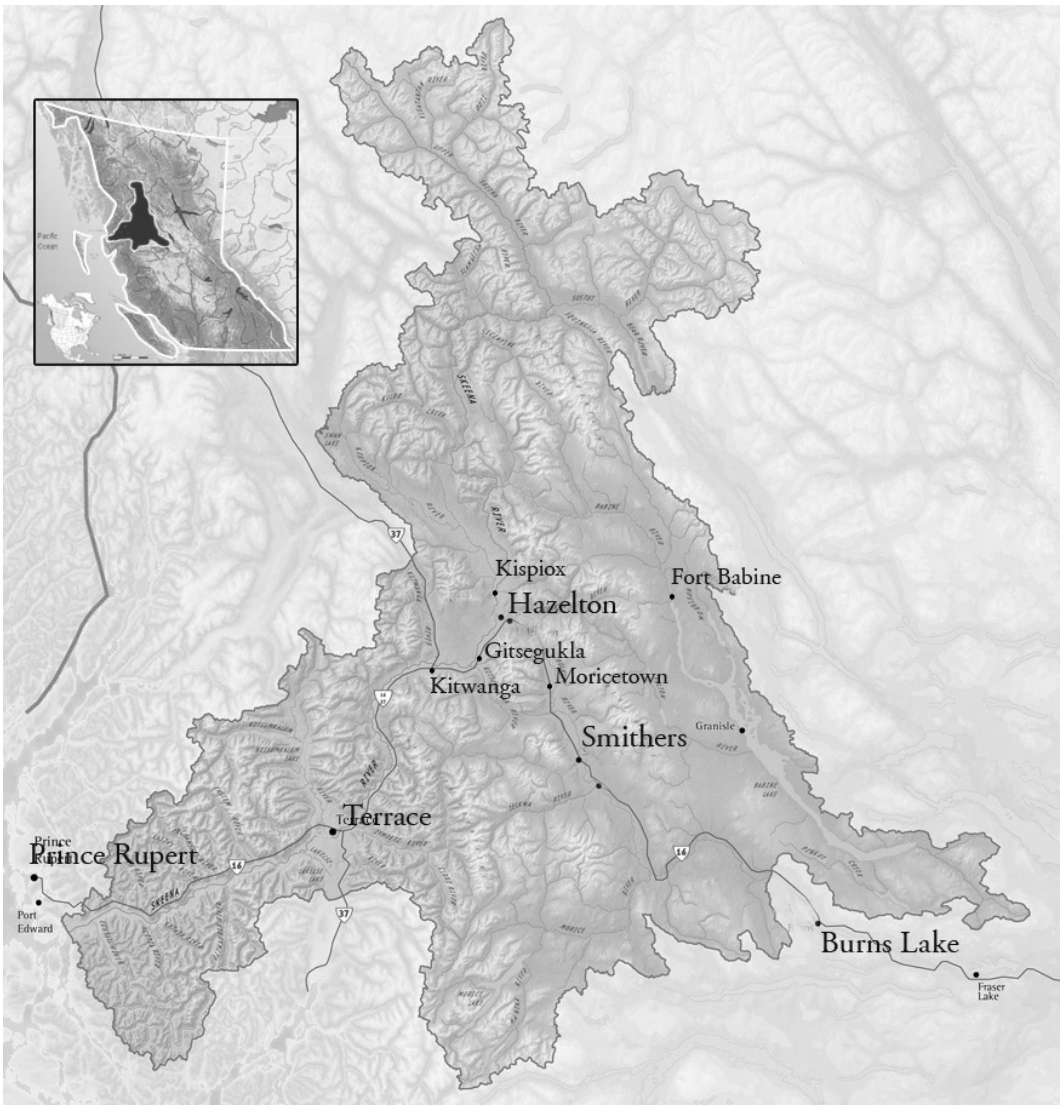

Figure 1: Map of Skeena Watershed (Ecotrust, 2009)

CHAPTER 1 – INTRODUCTION

North Pacific salmon populations have been deeply impacted by dams, resource extraction, harvesting, and urbanization (Waples et al., 2009). The Skeena faces many of these challenges, but despite extensive logging, and localized impacts from mining, urbanization, and agriculture, this watershed remains relatively intact, and large expanses of pristine habitats subsist (Gottesfeld & Rabnett, 2008). Unfortunately, the long-term health of the Skeena watershed exists in a tenuous state. Oil and mining companies see the area as a new frontier, and the region's rich resources have several large development proposals on the verge of becoming reality. To many, the Skeena is at a critical juncture, where the allure of high paying jobs poses direct conflict with maintaining an economy, culture, and way of life that has depended and thrived on salmon for millennia (Walters et al., 2008). This dilemma has been playing out in this region for decades, with a growing number of residents standing in unison against large corporations and governments pushing development perceived to threaten this way of life (BVRC, 2009). Overlying all of this are the impacts of climate change, already felt in mountain pine beetle infestations and receding glaciers (Gottesfeld & Rabnett, 2008, Walters et al., 2008).

The project described in this thesis offers a starting point for what might be part of a larger solution to growing land and resource use conflicts, and the challenges of climate change. It lays out a framework for implementing collaborative freshwater salmon habitat monitoring in the Skeena with the hope of stimulating discussions and implementation. Specifically, a collaborative habitat-monitoring program has the potential to:

- Identify the highest at-risk salmon habitats in the watershed, as well as their associated causes of degradation, and threats (DFO, 2005; SWGSRO, 2002);
- Track trends in the health of the watershed over time, and detect cumulative impacts (MacDonald, 2000).

This information is critical for enabling improved resource use planning, adaptive management, and restoration activities (Roni, 2005; SWGSRO, 2002; WSP, 2005) – thus helping alleviate concerns over resource development and protecting wild salmon in the watershed.

Federal and provincial governments also recognize that habitat and water monitoring programs are essential to protecting British Columbia's fresh water and fisheries resources. The need for, and intention to implement monitoring is highlighted in the federal Wild Salmon Policy (WSP), provincial Living Water Smart program, and recommendations of the provincially mandated Pacific Salmon Forum. These government policies and initiatives call for habitat monitoring projects to be implemented in select watersheds within the next few years (WSP, 2005; Living Water Smart, 2009; Pacific Salmon Forum, 2009). Further, both the federal government and the Pacific Salmon Forum have identified the Skeena as an excellent candidate for such a pilot due to its biological and anthropogenic attributes, and initiatives already underway (BVRC, 2009).

This research also has larger theoretical importance. Many collaborative salmon habitat monitoring frameworks and research describe what, how, and when to measure, how to store and analyze the data, and how to present results (DFO, 2005; SWGSRO, 2002; PNAMP, 2012). There is however little discussion in the available literature on

how to implement collaborative approaches and their associated governance structures. There is even less information on how to access resources and build the capacity necessary to carry out salmon habitat monitoring. My research appears to be unique in that it provides a holistic framework using a case study application to discuss key elements and approaches for implementation. These results can inform other salmon habitat monitoring initiatives around the North Pacific.

Through my research I developed insight and information about several topics that have been identified in the literature and a series of interviews as key parts of a collaborative salmon habitat-monitoring program. These include research and discussion on the importance of implementing a collaborative habitat-monitoring program, a review of potential indicators, an overview of current habitat monitoring capacity, discussions on the value of integrating this capacity, data collection and analyses, additional resource requirements, and governance structure. Conclusions and recommendations are offered in chapters 5 – 9, and summarized in chapter 10. The text summarizes research findings and offers some pragmatic approaches for discussion and implementation without the intention of being prescriptive.

CHAPTER 2 - RESEARCH APPROACH & METHODOLOGY

2.1 Approach, Methods and Rationale

I used methodological triangulation (Thurmond, 2001) which included an extensive literature review, formal and informal interviews, and participatory research to test my research questions. Triangulation is a widely accepted approach in social research to validate information obtained through qualitative research methods (Guion et al, 2011). Benefits of applying triangulation include increasing confidence in research findings, creating innovative ways of understanding different phenomena, revealing unique findings, providing a clearer understanding of the problem, and challenging or integrating theories (Thurmond, 2001; Guion et al., 2011). The primary disadvantage with triangulation is that it is time consuming. Other issues include disharmony based on investigator biases, lack of understanding about what strategies were used, and conflict because of theoretical frameworks (Thurmond, 2011).

The research methods I chose to triangulate - literature review, formal and informal interviews, and participatory research - are all common qualitative approaches used in social sciences (Patton, 2002; Marshall & Rossman, 2011; Kumar, 1996; Burton, 2000).

The literature review used a traditional approach (Cronin et al., 2008) to critique and summarize the body of information on environmental monitoring. Particular attention was given to studies and knowledge that focused on salmon habitat monitoring programs in the North Pacific, as these programs had the most relevance to the research questions. Information on salmon specific monitoring was however limited. To compliment this I reviewed collaborative environmental monitoring programs throughout

Canada and the US. This helped fill information gaps and expanded my knowledge on the successes and failures of similar programs.

The second portion of my literature review focused on data sources relevant to salmon habitat monitoring. Sources were selected based on whether they contained information related to the salmon habitat monitoring indicators recommended by the WSP Habitat Working Group (Stalberg et al., 2009) and in interviews with regional experts. Data sources were analyzed on whether they had acceptable collection standards, covered a large spatial and temporal extent, and their potential for integration into the program.

I conducted 12 formal and 7 informal interviews (referenced as pers comm.) with regional experts from the BC Ministry of Environment, BC Ministry of Forests Lands & Natural Resource Operations, federal Department of Fisheries & Oceans, regional environmental consultants, academic institutions, ENGO's, and First Nations. Interviewees were selected using purposeful sampling (DiCicco-Bloom & Crabtree, 2006) based on their expertise in monitoring relevant to Skeena salmon habitat. These were mostly technical staff from the above organizations involved in collecting and analyzing environmental monitoring data in the watershed. Follow up interviews and information requests were then conducted to fill knowledge gaps identified in the original interviews and literature review. The formal interviews were structured by asking a predetermined set of open-ended questions (Appendix E). This semi structured interview approach allowed participants to provide a depth of knowledge and elaboration on points they felt would be important for the program (DiCicco-Bloom & Crabtree, 2006). The open ended questions also allowed me to capture other points of

view without pre-determining those points of view, allowing for more objective results (Patton, 2002). The interview questions were designed from a preliminary literature review on habitat monitoring programs in North America and input from my thesis supervisor. Informal interviews were unstructured other than to question the participant on specific information gaps identified in the literature review and other interviews.

For the participatory research component of my project I took part in a Skeena Salmon Habitat conference (BVRC, 2009), DFO Salmon Habitat indicators workshop (DFO, 2012a; Stalberg et al, 2009), and the Skeena Watershed Initiative Habitat Working Group (SWI, 2012). Within these collaborative processes, I was representing SkeenaWild Conservation Trust as a proponent of salmon conservation in the watershed. My main focus was to advance technical information and analyses to improve resource management. Due to concerns of bias from my direct involvement and role as a conservationist (Car, 1986), all data and results were checked against conference and workshop proceedings, and meeting notes to ensure my conclusions were consistent with collaborative outcomes. Data triangulation with the literature review findings and structured interviews further assisted in minimizing bias (Patton, 2002; Car, 1986).

In analyzing the literature, interview, and participatory research results, I used a method known as saturation signaling - the point of data collection where no new themes emerge (Denzin & Lincoln, 2005; Creswell, 1998). From here I identified themes that recurred regularly in the different data collection methods through pattern matching (Yin, 2003). These were presented as important components and data sources for a successful Skeena salmon habitat monitoring program (Chapters 5 -9).

To guide and focus my research I designed two questions:

- Is there significant value in implementing a salmon habitat-monitoring program in the Skeena watershed?

And, if so,

- How can a program be implemented and operated in an effective and efficient manner to meet the objectives of understanding impacts to salmon habitat, and improving decision-making?

Both research questions were designed using the traditional cycle of design method (Marshall and Rossman, 2011). Questions were initially developed out of personal interest in the topic and reshaped through an iterative process, incorporating information from an initial investigation of the literature, and discussions with colleagues and academic peers. The first question was designed to test my assumption that a salmon monitoring program in the Skeena watershed would have value regionally, nationally, and informing monitoring initiatives around the North Pacific. This assumption was based on 10 years of salmon conservation work in Northern BC, and working with interest groups and government staff managing salmon throughout their Pacific range. The second question was developed through consultations with colleagues and salmon habitat managers during the thesis proposal stage. This approach recognized potential personal biases and was designed to minimize biasing results (Marshall and Rossman, 2011).

To answer the first question, I researched the watershed's fisheries resources, habitat diversity, and current impacts and threats. The purpose of this research was to assess the value and complexity of protecting Skeena salmon habitat to help maintain

and enhance long-term benefits to harvesters, communities, and the ecosystem (Chapter 3). I then researched the potential value and support for such a program at provincial and national scales (chapter 4). I specifically asked:

- What value does habitat monitoring bring to a watershed? My research focused on reviewing scientific literature on existing habitat monitoring programs (Section 4.1).
- What is the need from local, provincial, and national perspectives? I investigated local, provincial, and national needs through interviews, literature, websites, a Skeena salmon habitat conference, and personal interviews with fisheries / resource managers, and resource users (Section 4.2).
- Is there value in integrating current efforts? I assessed current monitoring efforts to see if fragmented data and capacity is limiting the ability to properly assess the status and trends of salmon habitat health (Section 4.3).
- What is the value and interest of using the Skeena as a pilot for government policies and initiatives that require habitat monitoring? I researched regional, provincial, and federal government support for using the Skeena as a pilot for implementing strategy 2 of the federal Wild Salmon Policy, Pacific Salmon Forum recommendations, and provincial Living Water Smart program. Investigations included literature research, personal interviews, websites, and participation in DFO and multi-party

WSP implementation processes within my managing role in a salmon conservation organization (Section 4.4).

Rationale for this approach: A fundamental initial step for any project idea is asking the question whether there is value in undertaking such a project. My definition of value included exploring the larger theoretical need for this research – how it adds to already existing body of environmental monitoring research. Through my research it was evident that there is both strong support for and value in implementing such a program, especially at a regional level. I therefore proceeded to answer the second question.

To answer the second question, I needed to understand; monitoring needs (what indicators), what monitoring capacity related to these indicators existed in the watershed, the fundamental components necessary to implement a program, how to form and structure a program (governance), and how to resource the program. Researching existing salmon habitat, and environmental monitoring programs, combined with simple logic, provided the basis for this approach.

The first step was to research what a Skeena salmon habitat-monitoring program needed to monitor. To answer this, I reviewed indicators which would provide information necessary to analyze the status and trends of salmon habitat health for the range of habitats found throughout the watershed (Chapter 5). A key piece of literature for this section was *Canada's Policy for Conservation of Wild Pacific Salmon: Stream, Lake, and Estuarine Habitat Indicators* (Stalberg et al., 2009). This paper provided an extensive review, analysis, and recommendations on salmon habitat indicators for WSP implementation in Western Canada, and was based on experience and expertise from

implementing salmon habitat monitoring programs in Washington and Oregon. I also reviewed indicators used in salmon habitat monitoring programs throughout the Western North Pacific through an extensive literature review and direct participation in a WSP habitat indicator workshop. Assessment was based on criteria used in choosing indicators under the WSP, and in programs in Washington and Oregon (Stalberg et al., 2009; SWGSRO, 2002). These included researching each indicator's:

- Relative strength in assessing stressors on salmon habitat, current habitat health, and changes in habitat quality and quantity over time;
- Cost effectiveness, including an assessment of the indicators current application in the watershed, and potential resources available to apply that indicator in the foreseeable future;
- Capacity to assess current and future impacts from industries operating within and external to the watershed impacting and / or potential impacting salmon habitat health;
- Having metrics with scientifically accepted impact thresholds, which define specific points where a habitat is at risk, and which management actions should be triggered.

Rationale for this approach: It was important to understand what needed to be monitored before I could understand the existing monitoring capacity in the watershed, and the challenges and requirements for expanding monitoring to meet the objectives of the program. My approach for assessing and recommending indicators was based on recommendations from existing salmon habitat monitoring experiences throughout North America (Stalberg et al., 2009; SWGSRO, 2002). It was important to assess

these indicators in a Skeena context to ensure my discussion and recommendations had practical application to the watershed.

The second step was to research what monitoring capacity exists in the Skeena related to the indicators recommended in the first step (Chapter 6). To answer this question I interviewed provincial and federal government staff, First Nations resource managers, academics, community groups, and ENGO's undertaking relevant monitoring in the watershed. I also reviewed literature, and investigated online databases. This information was then broken down to assess monitoring capacity and information on a sub-basin level (Appendix A).

Rationale for this approach: Personal interviews, literature, and data base research were the only practical means for assessing monitoring activities and capacity. Acquiring a basic understanding of existing capacity was necessary to assess information gaps, and to understand how existing efforts could be coordinated and expanded to meet the objectives of the program.

The third step researched the basic components and capacity required by the program to function effectively and efficiently (Chapter 7). Through the literature review of existing programs it became evident that the program would require; identifying and formalizing participants, sharing, collecting, and storing data, prioritizing monitoring efforts, expanding data collection to fill key data gaps, analyzing data to assess habitat status, trends, and risks, communicating the resulting information and analysis, integrating the resulting information into decision making, and acquiring the capacity to do all of this.

Rationale for this approach: Identifying the fundamental components of effective monitoring programs and assessing how they could be applied to the Skeena was both a necessary and logical component for developing a basic implementation discussion and approach.

The fourth step investigated multi-party governance structures and monitoring frameworks used by environmental monitoring programs in North America to assess their success and potential application to the program (Chapter 8). The academic literature provided several reviews of governance structures and their contribution to the success of monitoring programs (Creech, 2001; Pilze et al., 2005; IISD, 2012) Investigating a local monitoring program, the Babine Watershed Monitoring Trust (BWMT), complemented this research. I undertook personal interviews, and a literature review to assess the BWMT's success and the application of its governance structure to the program. A monitoring framework, specifically designed for WSP strategy 2 implementation (Wieckowski, 2011) was also assessed for its potential use and modification by the program, due to its close alignment with the proposed objectives of the program.

Rationale for this approach: Through the research I found that the success of environmental monitoring programs is significantly influenced by the governance structure of the program (Conrad & Hilchey, 2011; Creech, 2001). It was important to identify which governance structures were appropriate for application for the program, and which types of governance structures were most likely to support program success.

The fifth step researched the resources required to implement the program, and identified potential sources of funding (Chapter 9). The components discussed in step 3

(Chapter 7) were investigated to assess what resources would be required to implement them. I undertook personal interviews with technical experts, and a web site developer to assess costs associated with analyses, data management, and web site development. My personal experience managing a non-profit and developing budgets also contributed to the assessment. Expenses incurred by existing monitoring programs were researched as well. This was done in the context of what resources potential participants might be able to bring to the program to minimize expenses and operating costs. A simple budget was developed to guide thinking and offer a general idea of funding requirements. I also researched existing philanthropic investments in the watershed and British Columbia related to salmon conservation efforts, and offered a list of foundations and government grants that might be interested in supporting the program (Section 9.2).

Rationale for this approach: The program will require funding and sponsor support for implementation and to carry out its work. Researching North American and local environmental monitoring programs provided good insight into potential resource requirements and sources.

2.2 Data Gathering and Data Sets

Specific data were not gathered; however, I performed an extensive review of existing data sources relevant to salmon habitat monitoring in the Skeena watershed. Included in this review was an investigation of the Water Survey of Canada database (Water Survey of Canada, 2011) for water quantity data in the Skeena watershed, investigation of Environment Canada's CABIN database (Environment Canada, 2011a) for biomonitoring data in the watershed, and a review of DFO's water temperature data

(Finnegan, 2011). The Canadian data report *Review and Assessment of Water Quality in the Skeena River Watershed, British Columbia* was reviewed as a comprehensive resource of water quality information for the watershed (Remington, 1996).

CHAPTER 3 – OVERVIEW OF THE SKEENA WATERSHED

This section explores the value and uniqueness of Skeena salmon and threats to their habitat. This is the first of two research components to identify the value in implementing a Skeena salmon habitat-monitoring program. The second research component, exploring the value of habitat monitoring, is discussed in chapter 4.

3.1 Fisheries Resources

The Skeena is one of the most important and biologically diverse large intact wild salmon watersheds in the world. The physical landscape of the area is a key factor in the creation of this diversity. From headwaters high on the northern Skeena Mountains, the river flows over six hundred kilometers to the sea, cutting through the rugged Skeena, Hazelton, and Coast Mountains, mixing with the ocean in the heart of Canada's Great Bear Rainforest. Scientists from the Federal Department of Fisheries and Oceans and the Skeena Fisheries Commission have determined that within the six species of salmon present, there are approximately 300 stocks (individual populations) inhabiting the watershed. Twenty-eight species of freshwater fish have also been recorded (McPhail & Carveth, 1993). Multiple glacial periods helped create this diversity by forming habitat structures, altering watershed connectivity, and influencing colonization and re-colonization patterns (Waples et al., 2008, McPhail & Carveth, 1992). The Skeena produces the largest salmon and steelhead on earth, with some salmon weighing over one hundred and twenty pounds, and steelhead exceeding forty pounds. These giants evolved from the richness of cool glacier fed waters, abundant insects and zooplankton, fed in part by nutrients from previous salmon generations.

The Skeena is also home to a diverse mix of First Nations and British Columbians who hold deep ties to salmon. This rich culture and quality of life is correlated to the wealth of returning salmon and steelhead each year. For millennia Skeena salmon sustained and enabled advanced First Nation cultures and communities to develop and flourish. Communities continue to depend on salmon for culture, food, trade, and economic purposes (Gottesfeld & Rabnett, 2008). Skeena salmon also support an economy arguably larger than any other industry in the watershed. Wild salmon contribute over 100 million dollars annually to local communities, supporting world-renowned tourism, sport fishing, and commercial fishing industries (IBM, 2006).

Commercial net fisheries targeting Skeena salmon take place each summer in Southeast Alaska, in the marine approach waters to the river mouth, and in First Nations setnet and selective fisheries in the Skeena River's main stem, Bulkley and Babine tributaries. Sockeye are the most valuable species, though pink and Chinook are also harvested. Combined, Skeena salmon support Canada's second largest commercial salmon fishery, valued at over 15 million dollars per year (Blewet & Nelson, 2008). These fisheries provide a critical source of income to coastal and inland First Nations, and North Coast communities.

Large marine and river sport fisheries target Chinook, steelhead, coho, and sockeye. The Skeena is world-renowned for Chinook and steelhead fishing, argued by many to produce the finest angling anywhere - evidenced by the flood of sport fishers who arrive with the runs of salmon and steelhead each year. Sport fisheries contribute approximately 53 million dollars annually to local communities throughout the watershed (Blewet & Nelson, 2008).

A significant portion of the regions non-angling tourism can also be attributed to salmon. Ancient fishing sites such as Moricetown and Kitselas attract people from all over the world who witness First Nations harvesting salmon with traditional methods. Others come to experience wild salmon spawning in countless sites throughout the watershed, and the million plus sockeye returning to the Babine Lake system and its artificial spawning channels. Salmon are also vital to wildlife viewing opportunities, supporting high concentrations of Grizzly bears, wolves, eagles, whales, and many other species. The economic value of salmon to non-angling tourism is difficult to quantify, but is estimated to contribute 7.6 millions dollars a year to the local economy (IBM, 2006).

Beyond income, Skeena salmon and steelhead provide a quality of life envied by many around the world. Residents have excellent access to sport and food fisheries minutes from their doorstep. The importance of salmon was highlighted in a recent opinion poll which found over 80% of people living in the watershed are dependent on these fish in some manner, whether for employment, food, recreation, or culture (McAllister Opinion Research, 2009). Of these, First Nations hold the deepest ties. The Tsimshian, Gitanyow, Gitxsan, Tahltan, Wet'suwet'en, Ned'u'ten, and Takla have traditional territories occupying different regions of the Skeena. All seven nations continue to depend on salmon for their economy and culture, participating in commercial and food fisheries throughout the watershed and nearby coastal areas (Gottesfeld & Rabnett, 2008). Food, social, ceremonial fisheries (FSC) are a constitutionally protected right, and provide Skeena First Nations with hundreds of thousands of salmon each year for food and trade (DFO, 2010a). The importance of

FSC fisheries are impossible to quantify monetarily, but are essential to the health of First Nations, and their value to local communities is difficult to overstate (Gottesfeld & Rabnett, 2008).

3.2 Salmon and Habitat Diversity

The Skeena contains eleven major tributary sub-basins – Ecstall, Lakelse, Kalum, Zymoetz, Kitwanga, Kispiox, Babine, Sustut / Bear, Bulkley, Morice, and Upper Skeena (Gottesfeld & Rabnett, 2008). Together they make up British Columbia's second largest watershed at 54,432 square kilometers. This vast area supports a diversity of habitats across seven different biogeoclimatic zones (figure 1), transitioning from coastal temperate rainforest to dry interior boreal forest. Four ranges – the Kitimat, Hazelton, Skeena, and Babine, within the Coast Mountains – cover the watershed from Northwest to Southeast, providing a rugged landscape ranging from sea level to over 2500 meters in elevation (Gottesfeld & Rabnett, 2008). Further information on habitat and diversity by species can be found in Appendix F.

3.3 Current Habitat Issues and Threats

The Skeena has seen over a century of industrial activity and European settlement, mainly in the form of forestry, mining, agriculture, and linear developments (Gottesfeld & Rabnett, 2008). Despite this, the watershed has avoided many of the intense development pressures that have caused severe degradation in other large salmon ecosystems, such as the Fraser and Columbia (Walters et al., 2008). Most development in the Skeena have only caused local degradation (Walters et al., 2008), although forestry has been extensive, causing significant impacts in many parts of the watershed (Gottesfeld & Rabnett, 2008). Improvements to forest practices in the 1990's,

and decreases in harvest rates in recent years, have allowed many systems to begin repairing themselves (Gottesfeld & Rabnett, 2008). Regardless, forestry remains a major concern, especially in areas of the watershed which are currently pristine, and those such as the Kalum, Zymoetz, Lakelse, Morice and Babine watersheds, where harvest rates remain high (Gottesfeld & Rabnett, 2008; Walters et al., 2008). Cumulative impacts from forestry and mining may be having significant impacts on water quality in the Babine and Morice (Remington, 1995; Overstall, 2010).

Mining development in the Skeena remains localized to the Zymoetz, Upper Bulkley, Morice, and Babine tributaries, where acid mine drainage and metal leaching are a concern (Remington, 1995). Ongoing monitoring and treatment at these sites is essential to protect water quality and ensure minimal local and downstream impacts to fish (Remington, 1995). High commodity prices have recently renewed interest in exploration and development of the Skeena's rich mineral deposits (Walters et al., 2008). New proposals include the Morrison copper / gold mine proposal near Babine Lake and the Davidson mine proposal near at Hudson Bay Mountain. Of these, the Morrison mine proposal has received the greatest attention due to its potential to add acid and metals to the Morrison and Babine lakes systems, which is already impacted by two other mining developments (BCEAO, 2012; Overstall, 2010). It is not known whether the impacts from the Morrison mine proposal has the potential to exceed the natural capacity of Babine Lake to precipitate copper (Overstall, 2010).

The railway and highway have cut off significant side channel habitat in the lower watershed, impacted sedge habitat in the estuary, and enabled easier access to logging and mining resources (Gottesfeld & Rabnett, 2008). Several recent projects, such as

the Exchamsiks back channel rehabilitation project, have been successful in restoring habitat and access to affected areas (SEHAB, 2012). At present, serious concerns have been raised about potential spills from rail car derailments (Ritchie, 2012). The CN line runs the entire length of the Bulkley, and the main stem Skeena from Hazelton to Prince Rupert. Recent years have seen an increase in traffic, transportation of toxic substances such as condensate, and several derailments. Fortunately, none of these derailments have caused serious spills into the Skeena or Bulkley rivers (Ritchie, 2012).

The Kispiox and Bulkley sub-basins contain most of the agriculture, where cattle ranching and hay production are the primary activities. Agriculture seems stable with some localized stream bank destabilization, forest removal, effluent runoff, and water withdrawal issues (Remington, 1995; Gottesfeld & Rabnett, 2012). An exception is the Upper Bulkley tributary, with extensive forest removal, stream bank destabilization, and water withdrawals. Water licenses currently exceed the average summer stream flow by 2.4 times, and local populations of sockeye and Chinook salmon are at risk of extirpation (Remington, 1995; Gottesfeld & Rabnett, 2008).

Approximately 60,000 people live in ten small to medium size communities in the Skeena. Urbanization in these areas has had low impact on salmon habitat, although there is some concern regarding waste discharges into the Skeena and Bulkley Rivers (Gottesfeld & Rabnett, 2008). Cumulative effects from these are unknown, but are not thought to have a major impact on water quality (Remington, 1996). Lakelse Lake is an exception, where residential building around the lakeshore has had significant impacts on water quality and habitat (Gottesfeld & Rabnett, 2008). Run-off from septic systems, increased sedimentation, and aquatic and riparian vegetation removal are major issues.

In combination with forest removal and road building in the upper watershed, Lakelse sockeye populations have suffered serious declines since the 1990's (Wood, 2001; Gottesfeld & Rabnett, 2008).

Several oil and gas developments are proposed for the watershed, and are seen by local residents and First Nations to pose significant risks to salmon (BVRC, 2009). Coal bed methane (CBM) extraction has been particularly contentious due to its large footprint, and potential to pollute and alter surface and groundwater. In 2007 residents in the Bulkley Valley stopped the development of Telkwa Coalfield CBM Project (Cheadle, 2007). A second CBM project by Shell Oil in the Headwaters of the Skeena, Nass, and Stikine Rivers prompted strong opposition throughout the entire region. Opposition resulted in a four-year provincial government moratorium in 2008 (SWCC, 2010). More recently, Enbridge proposed the Northern Gateway Project (NGP) – a twin pipeline, which would carry bitumen from the Alberta Tar Sands to Kitimat. There, it would be loaded onto very large crude carriers and shipped to markets in Asia and the Western US. Within the Skeena, the pipeline would cross the Sutherland, Pinkut and Upper Bulkley watersheds, and follow the Morice River, Gosnell Creek, Burnie River, and then cross the Clore River (Enbridge, 2012). The proposal has met massive opposition from residents and First Nations across the province. Public concern deepened with the anniversary of the Exxon Valdez, the gulf spill, and the largest pipeline spill in US history from a pipeline owned and operated by Enbridge (O'Neil, 2012). NGP is currently undergoing a federal environmental assessment, which will take several years to complete and likely conclude with lengthy litigation (Jones, 2012). If approved, NGP could have adverse impacts to salmon habitat from increased

sedimentation, forest removal, altered water flows, and increased public access during the construction (Levy, 2009). However, oil spills from the pipeline and oil tankers pose the most serious threat to salmon. The region it would traverse is prone to landslides and avalanches. Landslides have ruptured the existing natural gas line four times since 1978 (Levy, 2009). Corrosion and technical failures are also a concern, and have plagued Enbridge on several of its pipelines in the US Midwest (Levy, 2009). Oil tanker spills also have the potential to adversely impact Skeena salmon. Spill models show that a moderate spill would affect huge portions of the North and Central Coast where Skeena salmon spend significant portions of their juvenile and adult life (Living Oceans, 2010).

While substantial portions of the Skeena have been impacted by a variety of developments, the watershed remains relatively healthy and intact overall (Walters et al., 2008; BVRC, 2009)). Large areas, such as the upper Skeena, upper Morice, and Lower Skeena tributaries are pristine (Gottesfeld & Rabnett, 2008). By many accounts, the Skeena is at a critical juncture, where protection of pristine habitat, careful development planning, and habitat monitoring are necessary to ensure salmon continue to benefit the people who live here (Walters et al., 2008; BVRC, 2009). At a larger scale, the Skeena remains one of the last intact large salmon ecosystems in the world where people and salmon have a chance at a healthy coexistence (BVRC, 2009).

CHAPTER 4 – VALUE OF HABITAT MONITORING

This section describes the importance of implementing salmon habitat monitoring through an extensive literature review of environmental and salmon habitat monitoring. Government Policies and regional initiatives are also investigated to assess support for implementing such a program. A discussion on the benefits of collaboration and pilot project implementation adds further insight on the potential value of a program.

4.1 Why Monitor Habitat?

Understanding the impacts of multifaceted land and water use decisions requires that we measure how our specific and collective actions impact salmon ecosystems. This knowledge allows us to take corrective actions, and undertake land use planning in a proactive and effective manner (McCollough & Espinosa, 1996). More specifically, monitoring tools permit management agencies and the public to assess habitat availability and condition on an ongoing basis, understand the effects of management prescriptions, and assess progress towards meeting intended goals and policy objectives (McCollough & Espinosa, 1996). Salmon habitat monitoring also allows for adaptive management responses to complex anthropogenic impacts (Ralph & Poole, 2003). Monitoring is therefore fundamental to salmon conservation, and necessarily linked to management objectives (NCWRC, 2011; Larsen et al., 2004).

Habitat monitoring uses indicators to measure ecosystem health and how it changes over time. Examples of indicators relevant to salmon habitat include; measurements of stream flow, sediment load, riparian vegetation, and water temperature, to name a few (McCollough & Espinosa, 1996). Important to an effective monitoring program is linking these specific indicators to the identification and use of

thresholds (Tallis et al., 2010; DFO, 2005). Thresholds (or WSP benchmarks) are scientifically identified levels where habitat quality and salmon health are compromised. In relation to salmon ecology, some indicator thresholds are well understood and easily defined, others less so (Salomon Consulting & Diversified Environmental Services, 2003). Defining thresholds provides a critical link between monitoring and management - setting actual trigger points for management actions (DFO, 2005).

Effective salmon habitat monitoring also requires that it be done on a scale appropriate to the intended level of protection. For salmon, appropriate scales include; demes, stocks, conservation units, aggregates, or species levels and their associated geographic regions (DFO, 2005). For this project I focus at the watershed level for several reasons. Watersheds are distinct units where hydrologic processes are intimately connected. What happens upstream affects what happens downstream, and vice versa, making resource management decisions important to the watershed as a whole (Meehan, 1991). Watersheds also contain genetically distinct populations of salmon called Conservation Units (CU's). CU level protection is important because it conserves the genetic integrity, spatial distribution, and resilience of salmon populations, which is a primary objective of the federal Wild Salmon Policy (DFO, 2005). Salmon within a watershed are also vital to the communities that exist there, and it is important to maintain healthy populations for their benefit. It is also important that communities within a watershed understand how their activities affect people upstream or downstream who rely on those same populations of salmon (Stouder et al., 1997). With community involvement, salmon habitat monitoring at the watershed scale can help provide this connection and understanding (Conrad & Hilchey, 2011; Pinkerton,

1999).

4.2 Relevant Policies and Initiatives

Large scale salmon habitat monitoring has been difficult to achieve (Ralph & Poole, 2003), and it's debatable whether it has been effectively implemented in Western Canada. It appears however that this is not because it is an unachievable goal, but because substantial work has not yet been taken to integrate the many parallel efforts at an appropriate scale (PFRCC, 2010; PSF, 2009). More specifically, government agencies responsible for resource management and environmental monitoring within a region operate largely in isolation from one another. In the past, most agencies have not integrated monitoring expertise and responsibilities. This silo approach to resource management and monitoring has been extensively identified as a barrier to effective salmon habitat management and monitoring (PSF, 2009; Mitchell, 2005). Fortunately, governments have recently made substantial progress developing policy, which recognizes both the necessity of habitat monitoring and a more integrated approach (DFO, 2005; PSF, 2009; Living Water Smart, 2009).

In relation to salmon on Canada's West Coast, both the federal and provincial governments are progressing at the policy level. The federal Wild Salmon Policy, provincial Living Water Smart Program, and recommendations of the provincially mandated Pacific Salmon Forum all define the necessity of habitat monitoring to protect salmon and water, and offer tools for protection. Implementation remains slow and somewhat elusive due to lack of political leadership, insufficient resources, inadequate inter-agency planning, conflicting mandates, and the lack of pilot project implementation

at a scale appropriate to protect large wild salmon ecosystems (PFRCC, 2010; Nelitz et al, 2008; Gardner, 2010).

Approved by the government of Canada in 2005, the Pacific Wild Salmon Policy (WSP) is a progressive plan to protect salmon abundance and diversity, and their benefits to ecosystems and communities. The WSP contains 6 strategies outlining specific actions to implement the policy and meet its objectives. Directly relevant to salmon habitat monitoring are WSP strategies 2, 3, and 4.

Strategy 2 - Assessment of Habitat Status - is designed to provide tools to inform decision makers and interest groups about how land use decisions are cumulatively affecting salmon habitat. This involves implementing habitat-monitoring programs at local scales to assess and monitor habitat on an ongoing basis, build collaborative habitat data systems, and develop impact thresholds where management actions should be taken.

Strategy 3 - Inclusion of Ecosystem Values and Monitoring - builds on strategy 2 with tools for maintaining ecosystem functions (i.e. nutrient loading, forage for aquatic & terrestrial wildlife). Specific actions include integrating ecosystem monitoring capacity into a habitat monitoring program, integrating climate change and ocean information into annual decision making processes, and informing decision makers when ecosystem values are at risk of not being maintained.

Strategy 4 - Integrated Strategic Planning - uses a multi-interest planning process to develop long-term strategic plans meant to protect the genetic integrity and habitat of CU’s. This process is tasked with implementing WSP strategies, including

those related to habitat protection and maintaining ecosystem functions. Monitoring, as described, is an important component of these.

To date the WSP habitat and ecosystem monitoring components of strategies 2 and 3 have not been implemented on a regional or watershed level. This is, in large part, due to a lack of resources, capacity, and political will, combined with the policies ambitious goals, and complexity in changing management regimes at federal, provincial and regional scales (Gardner, 2009; PFRCC, 2010). Progress has been made in developing a suite of stream, lake, and estuarine indicators under WSP action step 2.2. A review of these and other indicators, and their potential application to the Skeena, is the focus of chapter 5.

In 2004, the provincial government commissioned the Pacific Salmon Forum (PSF) to investigate issues and make recommendations on how to protect wild salmon in British Columbia. The PSF's first recommendation is to "apply an ecosystem based approach to managing all resources in watersheds and marine environments" (PSF, 2009). A major part of this recommendation is the establishment of habitat monitoring indicators to be applied and monitored at the watershed scale, starting with pilots in key watersheds. The PSF also recommended Implementing collaborative watershed governance projects designed to strengthen ecosystem management of watersheds

Several of the above PSF recommendations overlap with the strategies and objectives of the WSP. An important difference is that they are directed at the provincial government and the agencies making natural resource use decisions at a watershed scale. Unlike the WSP, PSF recommendations related to salmon habitat monitoring are not prescriptive in how they should be implemented.

British Columbia's water plan – Living Water Smart - provides additional provincial support for the ecological management of watersheds, improving water conservation, and establishing regulations to protect groundwater. Fundamental to the plan is monitoring of water quality and quantity to provide ecological, industrial, and community benefits (BC MOE, 2008).

In addition to the above provincial and national level policies and initiatives, people living in the Skeena watershed are demonstrating the need for salmon habitat monitoring. In 2004, residents, industry, and government recognized the necessity to fund and coordinate monitoring of natural resources in the Babine Watershed. This initiative resulted in the formation of the Babine Watershed Monitoring Trust (BWMT). The primary motivation of the BWMT is to ensure land use plan objectives are being met to protect ecosystem integrity and community values (BWMT, 2011). Central to these objectives are the maintenance of valuable salmon and steelhead resources in this large tributary of the Skeena. In the fall of 2009, the Bulkley Valley Research Centre hosted a Skeena Salmon Habitat Conference and workshop. The primary purpose of these events was to bring together a diversity of interest groups, government representatives, and experts to improve salmon habitat management in the Skeena. Participants acknowledged the uniqueness and importance of the Skeena as a large intact salmon ecosystem and identified the value of using the Skeena as a pilot project for implementing the PSF recommendations and the WSP (BVRC, 2009). More recently, the Bulkley Valley Research Centre has initiated a cumulative effects project for Northwestern BC, with specific focus on salmon in the Morice watershed.

4.3 Commonalities and the Value of an Integrated Approach

Common to all of these government policies and community initiatives is the need for habitat monitoring and integration. Both the federal and provincial governments are responsible for different aspects of managing fisheries and their habitats. For example, the federal Department of Fisheries and Oceans manages the harvest of salmon and the protection of fish habitat through the Fish Habitat Protection Provisions of the Fisheries Act, whereas the provincial government manages steelhead and freshwater species of fish, and sets land use regulations to protect fisheries and wildlife values for specific industries. The federal and provincial governments also undertake their own monitoring activities related to protecting fish habitat. This is further complicated by the fact that the provincial government has multiple agencies making land use decisions which affect fish habitat. An integrated approach is essential to reduce overlap and strengthen capacity (PSF, 2009). In addition, federal and provincial agencies do not have the necessary resources to effectively monitor salmon habitat (Gardner Pinfold, 2011). First Nations, community groups, and ENGO's bring additional monitoring capacity and resources, which, if integrated, may provide an effective watershed level monitoring program.

4.4 Using the Skeena Watershed as a Pilot Project

Many are looking to the Skeena as a unique opportunity to demonstrate new ways of implementing and integrating effective natural resource management (BVRC, 2009). Policy is also looking for a home, a place where government can test and revise how their initiatives can be applied on the ground. Pilots have been proven as an important step for instigating implementation across larger provincial and federal scales

(Vreugdenhil et al., 2010). This focus and opportunity is reflected in the following examples:

- The Skeena is one of two regional WSP implementation pilot areas in the province (SWI, 2012).
- The architects of the PSF have identified the Skeena as an excellent candidate watershed pilot project for implementing their recommendations (BVRC, 2009).
- The provincial Living Water Smart program implementation could be integrated into a water / salmon monitoring pilot program.
- Local residents, First Nations, and resource managers are interested and engaged in integrating resource management and habitat monitoring (BVRC, 2009).

Although only one part of these policies and initiatives, salmon habitat monitoring provides an important opportunity. It is a key element in all water and habitat conservation initiatives, and is essential for making sound land use decisions and revising strategies (Messer et al., 1991). A salmon habitat-monitoring pilot in the Skeena could provide a starting point for breaking down silos, integrating capacity, and attracting new resources to the region.

CHAPTER 5 – REVIEW OF POTENTIAL INDICATORS

Indicators of ecosystem health are at the core of any environmental monitoring program (Kovacs, 1992), and deciding on indicators is identified as an important initial step for monitoring implementation (Niemi & McDonald, 2004). In this section I review potential indicators for their application to the program. This review also helped guide my research in identifying monitoring capacity and gaps in the watershed, discussed in chapter 6.

5.1 Choosing Relevant Indicators

A key challenge in implementing effective salmon habitat-monitoring is choosing indicators that are relevant to understanding the current state, and changes to habitat health over time. Indicators must also be cost effective, easy to implement, and have effective metrics with scientifically defined thresholds (points where a habitat is significantly degraded or at risk) where possible (Stalberg et al, 2009; G.A Packman & Associates & Winsby Environmental Services, 2006; Cusimano et al., 2006). Table 1 provides a summary of salmon habitat indicators, their associated metrics, and benchmarks. It should be noted that different Indicators have different applications. While most apply to all species of salmon, many are specific to particular life history stages, and some, such as cold-water refuge zone and lakeshore spawning area, apply only to sockeye. Indicators are used in conjunction with one another, and a suite of indicators are required to assess the health and threats to all species and freshwater life history stages of Skeena salmon (G.A Packman & Associates & Winsby Environmental Services, 2006; Stalberg et al., 2009).

Indicator	Metric	Impact Benchmark (threshold)
WSP Recommended Pressure Indicators		
Total Land Cover Alteration	WSP: Roll-up data e.g., Watershed Statistics and report out on Total, and sub- indicators e.g., forestry, fires, urban, agriculture, other (possibly range) Alternative: Equivalent Clear Cut Area (where forestry is the predominant land use activity)	WSP: Relative ranking of watersheds (e.g., low, med, high) of total from distribution curve across watersheds.
Watershed Road Development	WSP: Road Density (km / km^2)	WSP: < 0.4km / km^2 = Lower Risk, > 0.4km / km^2 = Higher Risk
Riparian Disturbance	WSP: % of a stream's riparian area developed within 30 meters of the stream bank, reported on a watershed basis	WSP: 5% as first benchmark, subsequent categories determined via distribution curve of watersheds within the CU
Water Extraction	WSP: Volume licensed for consumptive use e.g., m3/yr, as a proportion of total yield summarized by watershed	WSP: Compare watershed ratios and rank based on proportion
Permitted Waste Management Discharges	WSP: N/A Alternative: Metal and acid discharge / leaching from mine sites	WSP: N/A Alternative: Permitted metal and acid discharge from mine sites (assess cumulative discharges and their associated impacts to set overall benchmark)
Other Pressure Indicators		
Threats	Potential Metric: Spatial mapping of Industrial and urban development	N/A
Groundwater Exploitation	M^3 Withdrawn	N/A
WSP Recommended State (Impact) Indicators		
Water Quality	WSP: N/A Alternative: Provincial Water Quality Standards, CCME Standards	WSP: N/A Alternative: Provincial water quality Standards, CCME standards
Water Temperature	WSP Juveniles (stream dwelling): Maximum Weekly Average Water Temperature WSP Adults: Maximum Daily Water Temperature during migration/spawning period	WSP Juveniles: Upper Optimum Temperature Range (UOTR) and Impairment Temperature (IT). Temperatures between UOTR and IT low/medium risk and temperatures above IT high risk. UOTR 15 degrees C IT 20 degrees C. WSP Adults: Upper Optimum Temperature Range (UOTR) and Impairment Temperature (IT). Temperatures between UOTR and IT low/medium risk and temperatures above IT high risk. • Chinook UOTR 14 degrees C IT 20 degrees C • Coho UOTR 14 degrees C IT 20 degrees C

		• Sockeye UOTR 15 degrees C IT 18 degrees C • Pink UOTR 15 degrees C IT 21 degrees C • Chum UOTR 15 degrees C IT 21 degrees C
Stream Discharge	WSP: Discharge m3 during Aug/Sept	WSP: Discharge (m3) <20% Natural Mean Discharge during Aug - Sept
Suspended Sediment	WSP: Total Suspended Sediments (mg/l, ppm)	WSP: • CCME • 25 mg/L in 24 hours when background is less than or equal to 25 • mean of 5 mg/l in 30 days when background is less than or equal to 25 • 25 mg/ when background is between 25 and 250 • 10% when background is greater than 250
Other State (Impact) Indicators		
Benthic Invertebrates	Reference Condition Approach	Skeena BEAST09 Bioassessment Tool Categories: • Reference Condition • Slightly Stressed • Stressed • Severely Stressed
WSP Recommended Quantity Indicators		
Accessible Stream Length	WSP: Kilometers Alternative: Accessible stream length, based on natural barriers	WSP: N/A Alternative: Assess against historic access
Key Spawning Areas	WSP: Total length (km) of spawning area per watershed and roll-up for the CU	WSP: N/A Alternative: Assess against historic spawning use
Lake Productive Capacity	WSP: Nitrogen and Phosphorous x Lake Surface Area.	WSP: Relative ranking of sockeye lakes (e.g., low, med, high) of total from distribution curve Alternative: Assess against PR mean mg C-m^{-2}-c^{-1}
Coldwater Refuge Zone	WSP: Width (m) as measured through dissolved oxygen and temperature profiles	WSP: Develop distribution curve of width of all sockeye lakes coldwater refuge zones and rank e.g., low, med, high risk.
Lake Shore Spawning Area	WSP: Total length of spawning area per watershed and roll-up for the CU	WSP: N/A

Table 1: Salmon Habitat Indicators recommended by the WSP Habitat Working Group, and Interviewees. (Stalberg et al., 2009)

Comprehensive reviews for salmon habitat indicators have been completed for application in Western Canada, which built upon similar work in Washington State and Oregon (G.A Packman & Associates & Winsby Environmental Services, 2006; Stalberg et al. 2009). The following section reviews the suite of habitat indicators chosen by the

Wild Salmon Policy (WSP) Habitat Working Group for their application to the Skeena. Additional Indicators recommended by the Washington State Department of Ecology and Pacific Fisheries Resource Conservation Council, and indicators already in use in the watershed, are also assessed for their applicability to the program (Cusimano et al., 2006; G.A Packman & Associates & Winsby Environmental Services, 2006, Bennett, 2009). It should be noted that only stream and lake indicators are reviewed for their potential use (see section 2.1 for selection methodology). Estuary indicators are critically important to monitoring salmon habitat health (Ryder et al., 2007), but are outside the scope of this project.

5.2 Types of Indicators

Indicators for salmon habitat status and trend monitoring are defined as three general types under WSP implementation; pressure, state, and quantity (Stahlberg et al., 2009) using a standard pressure, state, response framework monitoring approach (Bertram & Stadler-Salt, 2000; Ironside 2003). Pressure (also known as stressor) indicators are used to assess impacts on salmon watersheds and CU's mainly using remote sensing and vector data. Examples of pressure indicators include; GIS analyses of road densities, total land cover alteration, and riparian vegetation alteration (Stalberg et al., 2009; Bertram & Stadler-Salt, 2000). Pressure indicators can also include indicators to assess climate change impacts, including changes in glacial ice, snow pack, and mountain pine beetle infestation (Stalberg et al., 2009). State (also know as impact) indicators are used to measure the specific condition, or health of a habitat. Examples of salmon habitat state indicators include; water temperature, water quality, lake productive capacity, and benthic invertebrate health (Bertram & Stadler-Salt, 2000;

Stalberg et al., 2009). Quantity indicators are used to measure the amount of habitat available for salmon. Examples include; accessible stream length, key spawning areas, and lake shore spawning area (Stalberg et al., 2009).

5.3 Application of WSP Habitat Indicators in the Skeena Watershed

The following suite of indicators were recommended by the WSP Habitat Working Group for their application in monitoring salmon habitat in Western Canada under WSP Strategy 2 (Stalberg et al., 2009). Below is a discussion of their applicability to salmon habitat monitoring in the Skeena Watershed.

5.3.1 Pressure (stressor) Indicators

Total Land Cover Alteration is a widely accepted salmon habitat indicator (NOAA, 1996; Beechie et al., 1994; NOAA 1996; Bradford & Irvine, 2000), and may be comparatively straightforward to use in assessing stressor impacts on Skeena salmon habitat compared to other watersheds. Most areas of the Skeena are dominated by a single land use activity - forestry (Gottesfeld & Rabnett, 2008). Further, forestry has scientifically defined thresholds for the forestry equivalent clear-cut area metric, unlike some other land use related indicators (Stalberg et al., 2009). Large areas of pristine wilderness would also simplify analyses. Pristine regions can be monitored for land cover alterations over time to assess new impacts.

There are several sub-basins where additional land cover alteration analyses would be required. The Bulkley, Upper Bulkley, and Kispiox have significant agricultural activity (Remington, 1995), and both forestry and agricultural alterations would need to be assessed. Linear developments such as rail, road, power, and pipeline infrastructure

would also need to be incorporated into this indicator due to their impacts on forest cover, riparian vegetation, and fish passage (Bradford & Irvine, 2000).

Watershed Road Development has application to many Skeena sub-basins due to extensive forest harvesting and its associated road networks (Remington, 1995). Road densities have been widely correlated to salmon habitat degradation, and impact thresholds have been scientifically defined (Meehan, 1991; Bradford & Irvine, 2000). It should be noted that impacts from road densities on salmon habitats are correlated to geology, terrain (slope steepness), and precipitation (Meehan, 1991, Krisweb, 2011). Impacts in mountainous coastal areas of the watershed with high precipitation, likely occur at lower road densities than on the drier, flatter Nechako plateau. Thresholds need to reflect these differences. Watershed road development as an indicator was ranked high by the WSP Habitat Working Group, although the expense of obtaining the data is also high (Stalberg, 2009).

Riparian Disturbance is an important indicator due to a high level of forestry, localized agriculture, linear development, and their associated riparian impacts in many watershed sub-basins (Remington 1995, Stalberg, 2009). Percent of riparian area developed within 30 meters of a stream bank is a widely accepted riparian disturbance metric for assessing the health of salmon habitat (Stalberg et al., Cusimano et al., 2006). Riparian disturbance was rated high value by the WSP Habitat Working Group and is rated high throughout the literature for assessing salmon habitat health (Fausch & Northcote, 1992; Elliot, 2004; Hughes et al., 2004).

Water Extraction is presently of limited value as an indicator in the Skeena. According to Remington (1995, 2001), the only area of concern is in the Upper Bulkley

sub-basin where agricultural water withdrawal licenses exceed average summer low flow levels by approximately 2.4 times. There are currently no data on how much water is being extracted, and it is unknown whether excessive water licensing in this sub-basin is creating issues (Gottesfeld & Rabnett, 2008). Discharge could be monitored to asses whether in-stream flow needs for salmon are being met during July-September when potential issues might exist. Stream flow needs for fish passage over Bulkley Falls, avulsions, logjams, and beaver dams should also be assessed in the Upper Bulkley (Wilson & Rabnett, 2007).

Permitted Waste Management Discharges is an important indicator because several mines are discharging acid and metals into salmon bearing streams and lakes in the watershed (Remington, 1995). The Babine system for example has two mines discharging into the lake and another mine in the environmental assessment phase (Overstall, 2012). Considering this system contains the largest sockeye nursery lake in Canada, producing over 85% of Skeena sockeye (Cox-Rogers et al., 2010), it is important to assess the impacts of these discharges to understand whether they are potentially exceeding the natural capacity of the lake's water to precipitate copper (Gottesfeld & Rabnett, 2008). The effects of mine discharges need to be assessed in conjunction with forestry and mountain pine beetle impacts to understand the overall health of the system, and how it is changing. Mining discharges are permitted in the Morice / Bulkley sub-basin as well (Remington, 1995), and monitoring is important for similar reasons. Municipal waste is another permitted discharge, but is not thought to be a significant issue at this time (Remington, 1995).

5.3.2 State (impact) and quantity indicators

Water Quality indicator analyzes physical and chemical properties of water to assess whether they fall within acceptable standards. These analyses can assist in understanding a wide variety of potential impacts to salmon and their habitats (Bauer & Ralph, 1999). Water quality metrics also provide important insights into potential sources of contaminants (Chapman, 1996; Schulte, 2011). Water quality metrics also have widely accepted data collection and metric standards (Environment Canada, 2007).

Water Temperature indicator is valuable, inexpensive, and readily available for many sites within the Skeena Watershed (Water Survey of Canada, 2011; Stalberg et al., 2009; Rabnett pers comm.). Water temperature is an important indicator for understanding anthropogenic and climate change impacts (Gillis et al., 2011). Receding glacial ice, changing snow packs and precipitation, as well as effects from mountain pine beetle infestations, will alter temperature regimes in streams throughout the watershed in different ways. Monitoring water temperatures will assist in understanding these changes over time (Gillis et al., 2011).

Stream Discharge level monitoring is essential for understanding salmon health, especially for Chinook, coho, and steelhead (Hatfield et al., 2002). As with the temperature indicator, stream flow provides important information on climate change and anthropogenic impacts such as forestry and agriculture (Gillis et al., 2011; Meehan, 1991). Widely accepted benchmarks are available for this indicator (Stalberg et al., 2009). In addition to providing flow information to inform juvenile health, discharge can

provide important information on systems like the Upper Bulkley in relation to potential fish passage issues during adult migration (Wilson & Rabnett, 2007; Miller pers comm.).

Suspended Sediment can have serious impacts on adult and juvenile health and egg development in salmon (Henley et al., 2000), and is important for understanding forestry and agriculture impacts (Meehan, 1991). Difficulties arise where scant base line information exists prior to development to assess whether sedimentation is resulting form industrial activity or natural inputs (Meehan, 1991). Total suspended sediment (TSS) is the best available metric, with accepted standards (Canada Council of Ministers of the Environment) and thresholds (CCME, 2012). TSS however, requires laboratory analysis to achieve scientifically defensible results, limiting its application (Stalberg et al., 2009). The WSP habitat Working Group suggests site-specific correlation between TSS and turbidity as a potential substitute until more robust field analysis technology is developed (Stalberg et al., 2009). An assessment by local experts could evaluate the application of different suspended sediment metrics in the watershed.

Accessible Stream Length is a key indicator for species presence / absence in salmon watersheds (Nelitz et al., 2007a). An important consideration in applying this indicator is acquiring local expertise on how stream flows affect migration. Both fish passage over waterfalls, and dewatering through gravel fans affect fish passage in specific sites throughout the Skeena (Gottesfeld & Rabnett, 2008). Known examples which need further understanding include Gitangwalk Falls (Kispiox), Upper Skeena (above Duti), several small tributaries of Babine Lake, and Upper Bulkley Falls (Rabnett pers comm.). Culverts damaged during high water events can also create / alter

barriers, and need to be assessed and accounted for when applying this indicator (O'Hanley & Tomberlin, 2005).

Key Spawning Areas information is available for most Species and CU's for the Skeena Watershed (FISS, 2012; Skeena Watershed Initiative, 2011; Rabnett, 2012). These data are limited by the glacial turbidity of many tributaries and the main stem Skeena where visual assessments are difficult (Walters et al., 2009). Understanding key-spawning areas is further complicated by frequent high water events causing changes in channel morphology, flow rates, streambed particle size, and ground water upwelling areas (Rabnett pers comm.). Complementary indicators such as temperature, stream flow, dissolved oxygen, suspended sediment and spawning gravel information can be used to understand changes in key spawning areas over time (Platts et al., 1989). It may be difficult to assess key spawning areas for CU's with depressed populations where key spawning sites may be unused / underused until populations rebuild. Care should be taken for such populations when applying this indicator.

Lake Productive Capacity has been estimated for 29 Skeena sockeye nursery lakes using a Photosynthetic Rate (PR) model (Cox-Rogers, 2010). The modeling includes estimates of uncertainty to account for varying quality of data and natural fluctuations in photosynthetic rates. Updating these data periodically could provide productivity trend data. Although no specific benchmarks currently exist, this information could be compared to the estimated natural range of lake productivity for a specific lake. Further, additional photosynthetic rate data collection could provide better understanding of natural productivity ranges, as suggested by the WSP HWG (Stahlberg et al., 2009). An additional consideration in applying this indicator is the

importance of gaining information on the timing of plankton blooms and fry emergence to assess food availability during this critical life history stage (Hampton et al., 2006).

Coldwater Refuge Zone indicator is applicable to several important sockeye-rearing lakes in the Skeena. These include Kitwanga, Slamgeesh, Nilkitkwa, and Bulkley Lakes (Shortreed et al., 2001; Rabnett pers comm.). Most other Skeena nursery lakes have sufficient depth and cold water inputs to provide cool temperatures throughout the summer months (Shortreed et al., 2001; Gottesfeld & Rabnett, 2008). Local experts could complete an assessment of monitoring requirements for lakes of concern, including those listed above.

Lake Shore Spawning Area indicator may only be applicable to a portion of sockeye lakes in the watershed since many sockeye rearing lakes are glacial, and visual surveys are not possible (Gottesfeld & Rabnett, 2008). Groundwater upwelling areas are correlated to lake spawning locations (Young & Woody, 2007); therefore, it may be possible to use late fall / winter ice surveys and temperature assessments to detect spawning locations in glacial lakes. Differences in lakeshore spawning areas for different age classes of sockeye should also be considered when applying this indicator (Rabnett pers comm.; Dickson, 2010).

5.4 Application of Other Salmon Habitat Indicators

In addition to the indicators recommended by the WSP Habitat Working Group, benthic invertebrates, threats, and groundwater exploitation consistently received recommendation through personal interviews conducted under the project. Using these indicators to understand changes in Skeena salmon habitat is also supported in the literature (Wendling, 2008; Perrin et al., 2007; CCAP, 2012; RAP, 2012).

5.4.1 Pressure (stressor) indicators

Threats were considered to be an important indicator by the WSP Habitat Working Group; they felt this information could be captured in the narratives of CU habitat overview reports (Stalberg et al., 2009). It is important however that there is a comprehensive understanding of the spatial nature of threats. For example, information about mining tenure, access road, pipeline, power line, and other development proposals can be mapped and integrated into monitoring information inexpensively. It will be important to monitor the status of areas of watersheds and CU's where proposed development could risk salmon health.

In addition to development proposals, monitoring and modeling the effects of climate change, and analyzing mountain pine beetle infestation, receding glacial ice, and changes in average snow packs will provide important information for understanding and managing threats from climate change (BVRC, 2009). *Groundwater Exploitation* is not, at present, a significant issue in the Skeena (Remington, 1995; Gottesfeld & Rabnett, 2008). This indicator may have specific application to coal bed methane, and coal-mining development proposed for the Skeena headwaters. If the CBM moratorium is lifted groundwater could be substantially altered, withdrawn, and polluted through drilling, fracking, and removal of natural gas (Wendling, 2008). It will be important to gather baseline information and monitor impacts within the area of development. Chinook, coho, and steelhead are known to spawn within the tenure area (Rabnett and Wilson, 2009).

5.4.2 State (impact) indicators

Benthic Invertebrates are increasingly used as a bioassessment tool because they are a sensitive indicator of stream health, and reflect the cumulative effects to a stream and its surrounding environment (Bailey et al., 2004; Covich et al., 1999). This indicators applicability to the monitoring of salmon habitat was recognized by the WSP Habitat Working Group, and proposed as a potential indicator under WSP strategy 3 (Stalberg et al., 2009). Benthic Invertebrates are also a key water quality health indicator used extensively by Environment Canada in their Canadian Aquatic Biomonitoring Network (CABIN) program (Environment Canada, 2011). The Skeena is one of the most intensely biomonitored watersheds in the country (Bennett, 2009.

Benthic invertebrates are one of only a few indicators available to assess site-specific cumulative impacts. Biomonitoring of reference sites (sites unaltered by direct anthropogenic impacts) can also help assess climate change (Environment Canada, 2011a).

5.5 Selection Process

A process for finalizing a list of indicators and their application in the watershed can be undertaken with local experts - informed by WSP Habitat Working Group recommendations (Stalberg et al., 2009). A technical workshop was proposed by several people interviewed in this project to select a suite of habitat indicators, and review data sources for the program. This would be one of the initial steps for implementation.

CHAPTER 6 – CURRENT SKEENA HABITAT MONITORING CAPACITY

Effective implementation requires a comprehensive understanding of monitoring capacity, gaps, and trends (SWGSRO, 2002). The purpose of this section is to investigate programs producing data related to the indicators discussed in chapter 5, and their potential application and integration into a salmon habitat-monitoring program. Key monitoring gaps, and trends in monitoring capacity are also discussed to inform how the program might fill data gaps.

6.1 Overview of Skeena Habitat Monitoring

A suite of monitoring programs have been implemented in the Skeena over the past several decades in an effort to assess natural processes, industrial development, and climate change impacts on water quality, quantity, and aquatic health (Environment Canada, 2011b; Remington, 1995; Perrin et al., 2007; MOE, 2012; BVRC; 2009; CCAP, 2012; RAP, 2012). Programs are in place by Environment Canada, BC Ministry of Environment, First Nations, DFO, forest and mining companies, with additional efforts by community groups and ENGO's. The following list of monitoring activities is by no means exhaustive; the intention is to identify the main efforts producing relevant data. Appendix A provides additional detail on monitoring activities by sub-basin.

6.1.1 Water Quality & Quantity Monitoring

Environment Canada (Water Survey of Canada, Freshwater Quality Monitoring Program, Canadian Aquatic Biomonitoring Network) produces the majority of water quality and quantity information in the watershed (Environment Canada, 2011a; b). There are 25 active hydrometric stations operated by the Water Survey of Canada (WSC) (Figure 2). All 25 stations collect water level (m) and stream discharge (m^3/sec)

information on small, medium, and large tributaries. The WSC hydrometric station located on the Skeena main stem at Usk (just upstream from Terrace), is one of Environment Canada's core water quality monitoring stations used to calculate the national freshwater quality indicator. The Usk station monitors silver, cadmium, chromium, copper, nitrogen, phosphorus, lead, zinc, pH, and temperature to assess the overall water quality of the watershed, using the Canadian Council of Ministers of the Environment's (CCME) water quality index (Environment Canada, 2011b). As of 2011, a range of water chemistry information is also collected at the Bulkley River hydrometric site near Smithers. Two stations – Usk, and Quick monitor suspended sediment (Environment Canada, 2011b). The Nanika River station located in the Morice sub-basin is a Reference Hydrometric Basin Network (RHBN) station used in national and international programs to assess climate change.

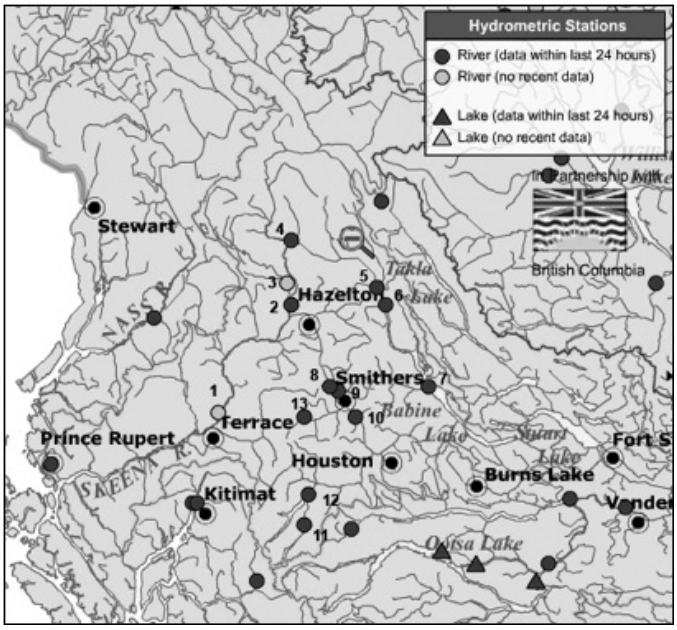

Figure 2: Water Survey of Canada Active Skeena Hydrometric Stations (Environment Canada, 2011b)

In addition to the 25 active hydrometric stations, 27 stations have been discontinued in the watershed (Appendix C) (Environment Canada, 2011b). Several of these have long-term data sets (> 10 years), which could provide important historical baseline information for the program.

Between 1994 and 2005, DFO monitored water temperature at 37 sites throughout the watershed (Appendix C) in conjunction with routine stock assessment activities (Finnegan, 2011). Water temperature and level information has also been periodically collected in the Lakelse, and Upper Bulkley watershed (Miller pers comm.). DFO conducted limnological studies of Skeena sockeye rearing lakes over many decades that contain both water quality and rearing productivity information. A summary of water quality information for 12 Skeena sockeye nursery lakes can be found in Shortreed et al., 2001. Remington (1996) undertook a review and assessment of water quality in the Skeena watershed in 1995. This report is an excellent reference for historical freshwater quality and monitoring information.

The BC Ministry of Environment collects water quality data to assess baseline information, water quality for public health, and aquatic impacts from mining and forestry operations (MOE, 2012). Specifically, coliforms, turbidity, nutrients, color, dissolved oxygen, chlorophyll a, and metals data are collected from 6 water quality sites in the Bulkley, and Lakelse sub-basins. Water quality data are also taken during site visits at biomonitoring sites (Appendix D) (Environment Canada, 2011a). Mining and forest companies involved in the water quality and biomonitoring outlined above provide monitoring support through funding and participation in data collection (Bennett, 2009; Perrin et al., 2007).

Gitanyow Fisheries Authority, Gitxsan Watershed Authority, Skeena Fisheries Commission, and Tahltan Fisheries collect water quality information in several sub-basins (Kingston, 2002; SFC, 2012; Rabnett & Wilson, 2009). Monitoring mostly consists of the collection of temperature and stream level data. Dissolved oxygen, conductivity, total dissolved solids, total suspended solids, nutrients, organic carbon, anions, and total metals data are also being collected at several stream and lake monitoring sites throughout the Skeena (Rabnett & Wilson, 2009; Kingston, 2002).

Local community groups, such as the Lakelse Watershed Society and community hatchery organizations collect water quality and quantity information on several small tributaries in the lower and middle Skeena, and Bulkley / Morice sub –basins (Lakelse Watershed Society, 2011). Most of those data are temperature and stream level information; however, extensive water quality sampling studies have been undertaken on Lakelse Lake and its tributaries (Lakelse Watershed Society, 2011).

6.1.2 Biomonitoring

The BC Ministry of Environment (Skeena Region) began biomonitoring sites using benthic invertebrates in the Skeena in the late 1990's (Perrin et al., 2007). The primary motivation for this work was to assess the effectiveness of forest harvesting practices in protecting aquatic ecosystems and their associated values. In 2004, a five-year multi-stakeholder effort involving B.C. Ministry of Environment, Houston Forest Products, BC Timber Sales, Babine Watershed Monitoring Trust, and the Premier Mine was initiated to develop a Reference Condition Approach (RCA) predictive model for use in Northwestern BC (Perrin et al., 2007). From this effort, the SkeenaBEAST predictive model was created in 2007 and rebuilt in 2009 to correct data errors and add

new reference sites. Since 2007, dozens of additional sites have been added, including the bioassessment of 59 streams in the Kalum, and Skeena Stikine Forest Districts (Bennett, 2009).

The BC Ministry of Environment has also been working with mining companies to biomonitor streams impacted by permitted waste discharge from mining operations. It is hoped that biomonitoring will become a standard monitoring technique for all mining activities in Northwest BC (Perrin et al., 2007; Tamblyn pers comm.; Sharp pers comm.). To date, over 200 sites have been biomonitored in the Skeena (Appendix D), and 100 of these provide reference condition information to compare against impacted sites (Environment Canada, 2011a).

6.1.3 Habitat Availability & Use Monitoring

DFO has undertaken extensive habitat availability and use monitoring in the Skeena, including - accessible stream length, key spawning areas, lake productive capacity, coldwater refuge zone, and lakeshore spawning area data gathering (DFO, 1991a-e; Hancock et al., 1983a&b; Jantz et al., 1989; Spilstead & Spencer, 2009). Most of this information is summarized in four report series with specific data on salmon species presence / absence, arrival and spawning timing, distribution of spawners by species, potential barriers, location maps for individual streams, and detailed stream maps. Reports include - *Stream Summary Catalogues* (DFO, 1991a-e)*, Catalogue of Salmon Streams and Spawning Escapements Series* (Hancock et al., 1983a&b)*, Catalogue of Salmon Spawning Grounds and Tabulation of Escapements in the Skeena River and Department of Fisheries Statistical Area 4.* (Smith and Lucop, 1966a-d; 1969)*,* and *Salmon Escapement and Timing Data Report Series* (Jantz et al., 1989). An

annotated bibliography of these and additional DFO escapement reports can be found in Spilsted & Spencer (2009). Annual escapement monitoring and research by DFO and First Nations fisheries programs (SFC, 2012; GFA, 2011; DFO, 2012c) provide additional information, which can be used to update data found in these reports, and provide some of the necessary information for monitoring spawning area and accessible stream length indicators.

Additional up to date sources for stream and lake spawning site information are found in - *Skeena River Fish and Their Habitat* (Gottesfeld & Rabnett, 2008*), SWI Skeena Sockeye Habitat Atlas* (Ecotrust Canada, 2011)*,* and the *Skeena Salmon Stock Status Report* (Rabnett, 2012)*.*

The provincial government's BC Fisheries Information Summary System (FISS, 2012) contains data on accessible stream length based on barrier locations for the entire province. It has been suggested in interviews that this information be ground-truthed by local experts and existing publications such as the DFO reports mentioned above, *Skeena River Fish and Their Habitat* (Gottesfeld & Rabnett, 2008)*, SWI Skeena Sockeye Habitat Atlas* (Ecotrust Canada, 2011)*,* and the *Skeena Salmon Stock Status Report* (Rabnett, 2012)*.* The Ministry of Forests Lands Natural Resource Operations posts all of its Skeena region fisheries report series, inventory reports, maps, and data on its website. Information includes steelhead-spawning locations for specific sub basins (MFLNRO, 2011).

Lake rearing capacity has been estimated by DFO for 29 Skeena sockeye nursery lakes using a Photosynthetic Rate (PR) model. This information can be found in *A Risk Assessment Model for Skeena River Sockeye Salmon* (Cox-Rogers et al., 2010),

and *Factors Limiting Juvenile Sockeye Production and Enhancement Potential for Selected BC Nursery Lakes* (Shortreed et al., 2001).

Coldwater refuge zone information is available for Kitwanga (Kitwancool) Lake from the Gitanyow Fisheries Authority (Kingston, 2004; Shortreed et al., 2001). The Skeena Fisheries Commission, Gitxsan Watershed Authority, and DFO have collected temperature profile data, which could assist in assessing coldwater refuge zone issues for Skeena sockeye lakes. A review of information specific to Slamgeesh, Bulkley, and Nilkitkwa Lakes should be undertaken to assess whether sufficient coldwater refuge zones exist, and to identify data gaps.

6.1.4 Stressor Monitoring

The Provincial government holds several vector data sets that can be used to assess total land cover alteration, watershed road development, riparian disturbance, and water extraction (Appendix B). None of these data sets provide sufficient information to comprehensively assess each indicator, several are out of date, and some would require expensive analysis (Stalberg et al., 2009; Pfalz pers comm.). The province also holds data on Mountain Pine Beatle infestation (Forest Health Data Set), which are useful in assessing climate change impacts (MOFR, 2012).

A collaborative ENGO project (SkeenaWild Conservation Trust, Headwaters Initiative, Rivers Without Boarders) produced current and proposed development vector layers for Northwest BC (NWBC development monitoring) (Pfalz & Rabnett, 2012). Data are current to November 2011, and include mining, forestry, oil and gas, linear (rail, power lines, pipe lines), industrial water licenses, and road development layers. This

information has particular application to monitoring total land cover alteration, watershed road development, and threat indicators.

The Bulkley Valley Research Centre (BVRC) is undertaking an integrated assessment of the cumulative impacts of climate change and industrial development on salmon in Northwestern British Columbia (BVRC, 2012). The project will assess the cumulative effects of a set of ecological and industrial scenarios on aquatic ecosystems, and their dependent terrestrial ecosystems in two study areas. One of the focus areas is the Morice sub-basin. This information will produce data layers with updated monitoring information for a wide range of indicators yet to be determined (Morgan pers comm.).

Academic institutions have undertaken two separate projects to assess climate change impacts in the Skeena. See section 5.4.1 for details.

6.2 Monitoring Gaps in Critical Salmon Habitat

The rich diversity of salmon and steelhead life histories, habitat requirements, and extensive stream accessibility throughout much of the watershed makes defining critical salmon habitat difficult. In reality, low gradient water bodies throughout the entire watershed are critical to at least one, if not many, of the watershed's salmon CU's (Gottesfeld & Rabnett, 2008). Further, dependence on clean water, nutrient, and structural inputs from upstream areas afford an argument for including the entire watershed in the definition of critical salmon habitat (Bisson et al., 2009). With this in mind, the purpose of this section is to identify some priority areas where monitoring efforts are inadequate to assess the health of some of the most productive and CU diverse salmon habitats in the watershed. Particular attention is placed on those high

value habitats with extensive land use impacts, and / or proposed large-scale development activities.

Habitat monitoring in the lower Skeena and tributaries below Terrace is limited at this time. Most tributaries are relatively pristine, and priority should be placed on the main stem where there is extensive logging in riparian areas, such as the Skeena River Islands (de Groot, 2005). Logging in such sensitive habitats has the potential to alter bank stability during heavy precipitation events - increasing sediment, and altering spawning and rearing habitats (Meehan, 1991). There are limited data on key spawning areas in this part of the watershed where a significant portion of at-risk chum populations spawn. The area is also important for a large portion of the watershed's pink salmon spawning, as well as Chinook and coho rearing habitat (Gottesfeld & Rabnett, 2008). Approximately 40% of the Skeena's flow originates from tributaries downstream of Usk (Gottesfeld & Rabnett, 2008)). No mainstem discharge measurements are taken in this region of the Skeena.

The Zymoetz sub-basin contains large runs of Chinook and steelhead, with significant populations of sockeye and coho. The area has been extensively logged, and has road, natural gas pipeline, and large power line corridors along most of the lower river, which have caused larger-scale damage to the floodplain (Gottesfeld & Rabnett, 2008). Extensive logging will continue into the foreseeable future, increasing total equivalent clear-cut areas in the upper watershed and remaining forested riparian areas. Oil, condensate, and natural gas pipelines have also been proposed to cross the Clore / Burnie main stems and tributaries (Enbridge, 2012; Apache, 2012). Baseline information should be collected in this portion of the sub-basin. While there is good

biomonitoring coverage on small and medium tributaries, the main stem lacks water quality and quantity information (Environment Canada, 2011a&b). Sedimentation is a particular problem, with two recent slides adding large amounts of sediment into the river system (Levy, 2009). It is not well understood how this increased sedimentation is affecting salmon and steelhead; monitoring of total suspended sediments should be undertaken.

The Sustut watershed has large populations of Chinook and steelhead, and significant populations of sockeye and coho salmon. The watershed was heavily logged in the 1990's and early 2000's, and a rail grade was built through the valley causing large amounts of sedimentation in the 1970's (Gottesfeld & Rabnett, 2008). Currently there is little habitat monitoring, and some evidence that the rail grade and extensive logging road networks are failing at stream crossings in the lower watershed (Vermillion pers comm.). Water quality and biomonitoring programs should be implemented to assess impacts from past logging, linear developments, and impacts from mountain pine beetle infestation.

The Upper Skeena is geographically extensive with large populations of steelhead and Chinook, and significant populations of sockeye and coho (Gottesfeld & Rabnett, 2008). Key spawning areas and habitat use for these species has only recently been investigated. It is important that this work be continued and expanded to gain insight into how proposed CBM and mining developments and climate change could impact CU's (Rabnett & Wilson, 2008). Collection of baseline water quality information is also important. Programs in place by Tahltan Fisheries and the Gitxsan Watershed Authority provide some of this information, but an expansion of water quality monitoring

is important, especially directly downstream of proposed developments. The majority of spawning is tightly linked to groundwater receiving areas (Rabnett, pers comm.), and monitoring should also be undertaken prior to development, if specific projects proceed.

Babine Lake produces over 85% of the sockeye in the Skeena. Its tributaries and the Babine River also support significant populations of Chinook, steelhead, and coho salmon, with lesser populations of pink and chum (Gottesfeld & Rabnett, 2008). The watershed has impacts from extensive logging, and mountain pine beetle infestation. Two closed mines have been increasingly leaching metals and acid rock drainage into the lake since the 1960's (Remington, 1996), and another mine located in the Morrison watershed is in the BC Environmental Assessment process. An oil and condensate pipeline is being proposed which would cross the headwaters of Sutherland River and Pinkut Creek (Enbridge, 2012). In recent years both wild and enhanced Babine sockeye have been experiencing declines in abundance and it is unconfirmed whether the issue is freshwater or marine in nature. DFO believes it could be a freshwater productivity issue, yet no water quality or lake productivity studies have been initiated to assess whether this is the case (Cox-Rogers & Spilsted, 2012; Peacock pers comm.). An investigation into water quality and lake productivity should be a top priority of a salmon habitat-monitoring program in the watershed.

Another important gap in information for Babine Lake is the extent of lakeshore spawning areas. Some historical information is available (McDonald, 1963, 1964), but a comprehensive lakeshore spawning area investigation needs consideration.

The Morice watershed contains large populations of Chinook, sockeye, steelhead, pink, and coho. The region has extensive impacts from forestry, as well as

from pine and spruce beetle epidemics and forest fires, and is viewed as a priority monitoring area by the provincial government and the Office of the Wet'suwet'en due to its high fish and fresh water values (Gordon, 2008). The two groups developed a comprehensive water-monitoring program for the Upper Morice (Morice Water Management Area), but it has never been fully implemented due to funding constraints (Sharpe pers comm.). Mining and oil / condensate / natural gas pipeline development proposals in the upper portion of the sub-basin make increased water quality, biomonitoring, and stressor monitoring timely and important, especially in the Gosnell and Morice River main stem areas.

The Upper Bulkley contains diminished populations of sockeye, Chinook, coho, and steelhead, and is one of the most heavily impacted sub-basins in the Skeena (Gottesfeld & Rabnett, 2008). Fish passage issues, and water quality impacts from agriculture, mining, linear developments, and logging require increased monitoring effort (Remington, 1995). Water quantity, obstructions, and temperature data are particularly lacking for the main stem of the Upper Bulkley River.

6.3 Trends in Monitoring Capacity

In relation to the indicators outlined in Chapter 5, government agencies are generally cutting back monitoring efforts in the watershed due to fiscal constraints. First Nations, academic institutions, industry, ENGO's, and community groups are generally desiring to, or increasing efforts to fill gaps in monitoring essential for understanding impacts from proposed and existing industrial developments and climate change. Many government and non-government monitoring efforts depend substantially on government funding sources at risk of funding cuts.

DFO undertakes the majority of salmon habitat use monitoring in the watershed, but has been experiencing funding cuts in stock assessment, habitat monitoring, and research since the 1990's (Langer, 2012). The federal government recently announced an additional 80 million dollar funding reduction to DFO over the next 3 years (May, 2011). This will undoubtedly affect their ability to conduct their legislated mandates, such as undertaking spawning area and lake productivity monitoring in the foreseeable future.

Environment Canada is responsible for a large portion of water quality and quantity monitoring in the watershed, but dramatically decreased the number of hydrometric stations through a rationalization program in the mid 1990's (Environment Canada, 2011b). The federal government recently announced cuts of over 700 jobs and 5-10% of Environment Canada's budget across the country over the next 3 years (Fitzpatric, 2011). It is unknown if or how this will affect the Water Survey of Canada (water quality, quantity), and the CABIN (biomonitoring) programs in the Skeena.

The BC Ministry of Environment collects water quality and aquatic health information to assess baseline information, water quality for public health, and aquatic impacts from mining and forestry operations (MOE, 2012). Presently, most of this effort is in the Bulkley, Morice, Babine, and Lakelse watersheds. Funding is generally stable and monitoring efforts over the long term are not predicted to change. Sampling efforts over the short term (next couple years) may be reduced due to the loss of a water technician (Tamblyn, pers comm.).

First Nations fisheries programs are mainly supported through federal funding sources, including the Aboriginal Fisheries Strategy and the Aboriginal Aquatic

Resources and Ocean Management Program (DFO, 2012c). Project specific funding is also occasionally available through the Pacific Salmon Commission Northern Fund and ENGO's. Funding is generally stable; however it is also unknown how the recently announced federal cutbacks to DFO will affect funding to First Nations fisheries programs. First Nations have been innovative in collecting habitat information, especially in relation to water quality and quantity in conjunction with their fisheries stock assessment and research projects (SFC, 2012). Field personnel opportunistically collect data while in the field on other fisheries related projects, and have expressed intention to continue this work (Cleveland pers comm.; Joseph pers comm.).

Community groups, local stewardship groups, and hatchery organizations have expressed interest in collecting salmon habitat information. Organizations like the Lakelse Watershed Society have dramatically increased their monitoring efforts in the last decade, along with their capacity to collect water quality, habitat, and biomonitoring information relevant to recommended indicators (Lakelse Watershed Society, 2011). One concern is the reliance of these groups on government funds to undertake their work.

ENGO's have significantly increased their interest and capacity to undertake stressor monitoring, and to support First Nations water quality monitoring in recent years (SkeenaWild, 2012; SWCC, 2012). Organizations like SkeenaWild Conservation Trust, and Skeena Watershed Conservation Coalition are interested in helping increase monitoring capacity in the watershed, and will likely play an important role in any future monitoring efforts (Huntington pers comm.). ENGO funding mainly comes through large

philanthropic foundations and individual donors who have taken an interest in Skeena salmon conservation (SWCC, 2012; SkeenaWild, 2012).

Academic institutions like the University of British Columbia, University of Montana, and the University of Washington have undertaken some innovative climate change analysis work in the Skeena (CCAP, 2012; RAP, 2012), with plans for future analysis and data collection. The SFU Department of Ecology is investigating setting up a fresh water ecology research station in the Skeena, and undertaking salmon and salmon habitat research (Moore pers comm.). Northwest Community College has been involved in collecting hydrology data in relation to run of river projects, and may bring expertise and capacity in future water quality and quantity monitoring. Academic institutions are increasingly interested in undertaking research in the watershed, and provide an important opportunity for increasing monitoring capacity.

CHAPTER 7 – MONITORING PROGRAM FUNDAMENTALS

The purpose of this section is to discuss elements necessary for the implementation of a collaborative monitoring program in the Skeena. These components were consistently identified in the interviews conducted under this project and are supported in the literature (IISD, 2012; Conrad & Hilchey, 2011; Milne et al., 2006).

Integrating monitoring efforts was repeatedly identified as essential to the success of the program (DFO, 2005; PSF, 2009) and habitat protection in the Skeena (chapter 4) (BVRC, 2009). There was consensus that government agencies, First Nations, industry, community groups, academic institutions, and ENGO's should collaborate to identify goals, share data, identify data gaps and priority areas, access and share resources, and apply enhanced monitoring efforts (Milne et al., 2006; Conrad & Hilchey, 2011). More specifically the research supported that program success requires:

- Agreeing on a set of specific goals and objectives for the monitoring program;
- Acquiring the capacity to gather relevant monitoring information produced by the various governments and interest groups;
- Increasing data collection to fill key data gaps;
- Organizing and housing the data in an accessible and user friendly data base;
- Using these data to assess habitat status (with a focus on high priority habitats) and trends in relation to indicators; and,
- Communicating this information to government agencies, First Nations, interest groups, and the public in an ongoing and focused manner.

Beyond sharing monitoring information and analyses, linking this information to management was identified as important to maximize the effectiveness of the program (Milne et al., 2006; Conrad & Hilchey, 2011). For example, opportunities were identified to use monitoring information and analyses to:

- Implement strategy 2 and develop linkages to strategy 4 of the WSP (DFO, 2005);
- Assess the effectiveness of sub-regional land and resource management plans (Price & Daust, 2009; BWMT, 2011);
- Assist First Nations in assessing proposed development and potential adverse impacts (Gordon, 2008);
- Develop adaptive management approaches to sub-basin restoration and CU recovery plans (DFO, 2005).

The following is a discussion of these key aspects of a Skeena salmon habitat-monitoring program.

7.1 Program Participation

Receiving buy-in prior to the design stage is important, especially with government agencies and First Nations collecting relevant data within the watershed (PSAMP, 2008; Conrad & Hilchey, 2011). Environment Canada, Water Survey of Canada, DFO, BC Ministry of Environment, BC Ministry of Forests Land Natural Resource Operations, the Babine, Wet'suwet'en, Gitxsan, Gitanyow, and Tsimshian Nations are all key data holders and data collection entities in the Skeena (Environment Canada, 2011a&b; MOE, 2012; MFLNRO, 2011; SFC, 2012, GFA, 2012). Preferably, all of these governments would participate in program design and implementation.

Community groups, ENGO's, academic institutions, municipal governments, and additional government agencies have the potential to add significant capacity. Their participation in the program design and implementation phase is also important. It is possible to implement a monitoring program with limited participation by taking advantage of those entities and people who are supportive (Koontz et al., 2004). Data contained in government databases are public; this wealth of monitoring information can be integrated regardless of participation and support of the program.

7.2 Setting Goals and Objectives

Implementing a salmon habitat-monitoring program and using this information to help protect salmon is a likely overarching goal for the program. Beyond agreeing to such high level goals, it is important for participants to define clear objectives prior to program implementation that define the desired state or outcomes of the program (Roni, 2005). At a watershed scale, objectives may be broad, such as identifying, monitoring, and analyzing the highest priority / most at risk habitats (Wiekowski, 2011). At finer scales, such as a sub-basin or CU, monitoring objectives will become more specific – such as monitoring the health of specific life history stages of a particular salmon population (see Figure 6).

7.3 Data Sharing, Collection and Storage

Data is currently collected and stored in a fragmented manner making it difficult the access and share across jurisdictional boundaries and amongst First Nations and interest groups. The following section discusses how data can be effectively collected, stored and shared. It also investigates standardization of data collection to assist quality control and sampling design, and to improve confidence and accuracy in data

interpretation. Protocols are also discussed with the goal of making participants comfortable with sharing data.

7.3.1 Data Sharing and Storage Systems

Integrating data from the various sources outlined in chapter 6 and new sources, into a data base that is properly catalogued, easily accessible, and updated, is a core component of any habitat monitoring program (Lengyel et al., 2008; Milne et al., 2006). Habitat monitoring programs have traditionally used hardware systems to store, manage, and access data. These systems are expensive, difficult to manage, difficult for individuals to upload to and download information from, and require someone with the expertise to manage and fix system issues (Strickland, 2008; Pfalz pers comm.). New systems called cloud storage offer a user-friendly alternative, and are quickly becoming standard for data storage and sharing for a variety of applications (Dikaiakos et al., 2009). Cloud storage systems are a web-based storage device, removing the need for hardware and their management requirements - users need only manage the data, not the system. Cloud systems are also inexpensive compared to traditional hardware storage systems - users pay for uploads, downloads, and moving files around, by transaction (Strickland, 2008). Further, users can upload, download, and manage data from any computer interface. This type of data management system is being employed locally by the Babine Watershed Monitoring Trust for similar purposes as would be required by a watershed salmon habitat monitoring program (Pfalz pers comm.). Examples of common cloud data management systems include Amazon Simple Storage (Amazon S3), Google Cloud Storage, and VMware.

Once a cloud data management system is in place, participants in the program can upload new data as acquired, and download data on an as-needed basis. The system will require an expert to organize the data, and ensure data quality protocols are followed. It should be noted that some of the government agencies outlined in chapter 6, such as the Water Survey of Canada, and Environment Canada CABIN program, already have effective data management and sharing systems (HYDAT, CABIN database). Data from these programs / systems don't necessarily need to be integrated into a watershed data management and sharing system because they are already accessible to the public, and well managed. In the case of the CABIN program, data from all biomonitoring data collection entities (BC Ministry of Environment, forestry operators, and individuals using CABIN data collection protocols) are uploading their data to the CABIN database (Environment Canada, 2011a). There is therefore a reduced need to integrate these data. The Water Survey of Canada (WSC), however, only archives and manages data from WSC hydrometric stations, and related BC Ministry of Environment partnership programs (Environment Canada, 2011b). Any additional water quality and quantity data collected by non-government agencies are not included. A discussion should occur with WSC to assess the potential of integrating non-government water data into their database. An alternative would be to store and manage all of, or just the non-government water data, in a watershed data management / sharing system.

One issue with developing a collaborative watershed data management and sharing system is the potential for users to upload data not relevant to the program. Criteria should be developed and agreed to up front, which outlines specific objectives

and purpose, to avoid compromising the effectiveness of the system (Pfalz pers comm.). Restricting upload access to specific individuals can further assist in minimizing potential problems.

7.3.2 Data Collection Standards

The lack of data collection standards and protocols is a key factor limiting the success of collaborative monitoring programs (Milne & Hilchey, 2006; Conrad & Hilchey, 2011); therefore, standardization is important in program design. The government agencies discussed above have national and provincial data collection standards and training programs in place for collecting water quality, quantity, and biomonitoring information (MOE, 2012; Environment Canada 2011a&b). To participate in data collection for a watershed salmon habitat-monitoring program, all participants should agree to adhere to government data collection standards for indicators with existing government standards. There should also be flexibility for First Nations, conservation, and community groups using data collection tools and techniques not employed by government programs (i.e. solinst data loggers, turbidity meters) to be incorporated into the program, if scientifically defensible.

Data collection for habitat quality and use related indicators (accessible stream length, key spawning areas, lake shore spawning area, cold water refuge zone, lake productive capacity) are not standardized. However, DFO and First Nations fisheries programs employ bilateral, multilateral, and Canadian (CSAS) scientific review processes to validate the techniques and data employed for monitoring related to these indicators (DFO, 2012b). Participants collecting data for habitat quality and use related indicators should discuss and agree upon data standardization (informed by WSP

Habitat Working Group recommendations) to ensure data are comparable over time for trend monitoring.

Data used to assess pressure state indicators (GIS) are not formally standardized. GIS analysts however, usually draw from limited data sets (mostly government) for most of the indicators of interest, which often results in a fairly uniform application and use of data. Investigating and agreeing on a standardized approach for GIS related indicators could be achieved in a workshop setting involving government and non-government technical experts (Pfalz pers comm.).

The WSP Habitat Working Group provides data collection standard recommendations associated with many of the indicators discussed in chapter 5 (Stalberg et al., 2009). One of the objectives of the implementation process recommended in chapter 10 should be to discuss and agree on data collection standards for program participants related to each specific indicator incorporated into the program. Proper metadata (where, when, how, and who collected the data) collection is a key part of any useable data, and requirements should be made explicit during the design phase (Radermacher, 1991).

7.3.3 Monitoring Sampling Design

Choosing an appropriate sampling design is another important aspect of implementing effective monitoring (EPA, 2002). Some commonly used sample designs include simple random sampling, systematic random sampling, and a generalized random-tessellation stratified designs (Lohr, 1999; Wieckowski, 2011; EPA, 2002). Each has strengths and weaknesses, and choosing the proper sampling design requires appropriate technical expertise. The main goal is to obtain precise estimates while

minimizing costs. Defining the desired confidence in detecting whether differences have occurred, or a threshold has been met for a particular indicator, needs to be defined and incorporated into sampling design prior to monitoring. The desired statistical power to detect change in the condition of a habitat or CU also requires consideration. The answers to these questions will depend on available resources, and the degree of certainty required to influence management (Wieckowski, 2011).

7.3.4 Data Sharing Protocols

Data sharing protocol agreements are standard practice in collaborative data sharing arrangements, and may be essential to gain involvement from potential participants, protect proprietary interests, and ensure proper accreditation (Savan et al, 2003). Such agreements do not necessarily need to be formal, depending on the level of trust among participants. Some form of written understanding for data sharing should be developed during the design phase. Existing agreements need to be respected by program participants.

7.4 Prioritizing Monitoring

Resources accessed under a salmon habitat-monitoring program should be prioritized to those areas of the watershed with the highest fish values, impacts, threats, and where gaps exist in current monitoring efforts (DFO, 2005; Stalberg et al, 2009). An effective way of focusing monitoring efforts is to agree on a set of questions at the outset. For example, participants might ask – what Skeena salmon CU's are most at risk from freshwater habitat impacts? Local expertise, and information such as that contained in section 6.3 can be used to identify an initial set of sub basins or CU's at high risk. GIS Pressure analysis, and habitat status reports can be used to assess the

initial list and identify priorities (Stalberg et al, 2009; Wieckowski, 2011). Mapping current and past data collection sites in the watershed should also be done to assess spatial data gaps for relevant indicators. In conjunction with a monitoring framework (see section 8.3), these tools can assist local experts in identifying key monitoring gaps and help prioritize where capacity and funding should be focused for field-based sampling. A similar approach was recommended by the WSP Habitat Working Group (Stalberg et al., 2009), and supported by Wiekowski (2011).

7.4.1 Pressure Analyses

Comprehensive pressure analyses will complement local expertise by providing visual information and analyses on whether thresholds have been met or exceeded for pressure indicators (Stalberg et al., 2009; Bradford & Irvine, 2000; Richards & Host, 2007; Wieckowski, 2011). Local GIS capacity exists within the watershed to assess total land cover alteration, watershed road development, and riparian disturbance indicators (ILMB, 2007). These assessments would determine whether thresholds (as recommended by the WSP habitat working group, scientific literature, and determined by local experts) for the metrics associated with each indicator have been approached or exceeded for sub-basins of concern. Where available, climate change, cumulative effects, and proposed development information, and their potential impacts to salmon habitat, should also be detailed in the sub-basin pressure analysis reports. Alternatively, the steps to assess pressures and threats could be incorporated into the habitat status reports discussed below.

7.4.2 Habitat Status Reports

Habitat status reports offer an important tool for comprehensively investigating and reporting habitat issues and their associated monitoring, protection, and restoration priorities (DFO, 2005). It is recommended that a habitat-monitoring program initiate habitat status reports for sub-basins found to be at high risk from pressure and expert analyses (DFO, 2012a). Several habitat status reports have been commissioned by DFO, under WSP implementation, on Vancouver Island and in the lower mainland (DFO, 2012a). These reports offer a reference for designing habitat status reports for the Skeena. Objectives of the WSP habitat status reports include:

- Summarizing characteristics and condition of fish habitat within a specific watershed;
- Identifying factors limiting fish production and high value habitats important to production and that require protection;
- Identifying potential habitat indicators and benchmarks (thresholds) to monitor the status of fish habitat in a watershed over time;
- Assessing WSP indicators against their recommended benchmarks, where sufficient data are available;
- Outlining priorities for habitat protection, rehabilitation, and restoration, and identifying specific rehabilitation projects that target key degraded habitats;
- Outlining data gaps with respect to understanding limiting or high value habitats.

DFO has also designed habitat status templates, which provide a structure for reporting habitat characteristics, issues, limiting factors, indicator assessments, and restoration opportunities by life history stage for the five species of salmon (DFO, 2012a).

7.4.3 Mapping Monitoring Efforts

Mapping current and past efforts will help identify monitoring gaps for the suite of indicators in the watershed as a whole and high priority sub-basins and CU's (WDFW, 2012). A program such as Google Maps provides a relatively easy and cost effective program for integrating and displaying collection sites and their associated meta-data (Pfalz pers comm.; IWMI, 2012). Environment Canada has interactive mapping tools available for water quantity and quality (HYDAT), and biomonitoring information (CABIN) (Environment Canada a&b). With permission, these data layers could be integrated into the watershed-monitoring map, simplifying the process. Monitoring data from other government agencies, First Nations, and community groups can also be integrated.

The resulting watershed-monitoring map could both inform the adequacy of monitoring efforts, and be integrated into the data sharing and storage system discussed above. The CABIN database provides a useful example of such a map-based tool. Users simply click on the data location they are interested in to access its associated data (Environment Canada, 2011a).

7.4.4 Local Expertise

A wealth of expertise and knowledge exists within the watershed to help identify priority areas and monitoring gaps, and guide monitoring efforts (BVRC, 2009). As First Nations hold significant amounts of scientific information and traditional ecological knowledge, their participation in prioritizing monitoring is strongly recommended.

Ideas on how participants and tools can be structured to guide monitoring decision-making are discussed further in chapter 8 – Program Governance & Structure.

7.5 Expanding Data Collection

Numerous user groups, government agencies, First Nations, conservation and community groups, and academic institutions spend significant time working, recreating, and collecting data throughout the Skeena. These people have a vested interest in protecting salmon habitat and water quality, and are a tremendous resource for expanding monitoring capacity in an efficient and cost effective manner. The following is an overview of potential partnerships, equipment, and training options to expand monitoring related to the indicators recommended in chapter 5.

7.5.1 Data Collection Opportunities

First Nation fisheries programs operated by the Tsimshian, Gitanyow, Gitxsan, Wet'suwet'en, Lake Babine Nation, and Talhtan receive government funding to undertake stock assessment and scientific work in their respective territories (SFC, 2012; GFA, 2012; Office of the Wet'suwet'en, 2012). Interest and capacity may exist within these programs to expand data collection for water quality, temperature, and quantity indicators in conjunction with their current monitoring activities. This could be as straightforward as installing data loggers at stock assessment sites, downloading data at the end of the field season, and uploading data to the watershed data management and sharing network. Crews could also assist in collecting water quality samples at current stock assessment sites, and biomonitoring.

A specific opportunity exists with the Wet'suwet'en in the Morice sub-basin, where an agreement with the BC Ministry of Environment has identified 40 monitoring sites for water quality, quantity, temperature, and biomonitoring data collection (Gordon, 2008). This agreement has one year of data collection (2009), and its implementation is

currently limited by lack of resources (Tamblyn, pers comm.). A salmon habitat monitoring program should consider assisting the Wet'suwet'en in acquiring resources to monitor sites established in this agreement, especially those considered high priority through the monitoring priority analysis outlined in section 7.4.

Individual First Nations may also be interested in participating in collecting biomonitoring data at established sites in the watershed. This would necessitate training under Environment Canada's CABIN program (Environment Canada 2011a).

DFO stock assessment and habitat staff present another opportunity for collecting water quality, temperature, and quantity data in conjunction with stock assessment and habitat assessment and restoration activities. Data loggers could be installed at sites monitored for temperature from 1994 – 2005 (Finnegan, 2011), where stock assessment activities remain active. DFO staff are also a link to community stewardship groups, such as the Lakesle Watershed Society, and streamkeeper groups in Hazelton and Houston (DFO, 2012d). They may have the capacity to assist these groups with data collection training, coordination, and data management.

Water Survey of Canada (WSC) staff make regular maintenance and data collection visits to 25 hydrometric sites in the watershed as part of the national water quantity-monitoring program (Environment Canada, 2011b). It should be investigated whether the WSC would be willing to install temperature gauges, collect water quality, and / or macro invertebrate samples at some or all of these sites to assist the program.

Industry is not currently required to share data or integrate it into government databases (Morgan pers comm.). Individual mining, forestry, and energy companies

may be willing to share existing data and collect additional data at their operating sites in the watershed.

Community groups such as the Lakelse Watershed Society are already active collecting data related to indicators discussed in chapter 5 (Lakelse Watershed Society, 2012), and may be interested in expanding their efforts. Others, such as local streamkeepers groups in Hazelton and Houston, as well as community hatchery groups like Deep Creek, Toboggan, and Chicago Creek may be interested in assisting with data collection. Additional opportunities to participate in monitoring may exist with groups such as Northwest Watch, Friends of the Morice Bulkley, and outdoor recreation clubs.

SkeenaWild Conservation Trust is considering developing a River Keepers program for the Skeena modeled after successful programs on the Columbia and Fraser (Columbia Riverkeepers, 2012). Under this program, community members from throughout the watershed would adopt sections of the Skeena and its tributaries. Primary activities would include garbage removal, restoration, and monitoring activities (Brown, 2012).

Fishing guides operate in all of the Skeena's major salmon and steelhead bearing streams from March – November each year. Their intimate knowledge and regular access to remote and difficult locations provides a unique data gathering opportunity. Due to their reliance on the resource, guides may be interested in participating in the program and in integrating data collection into their daily guiding activities. In some locations such as the Upper Skeena, Sustut, and Lower Skeena tributaries, guides are often the only people visiting potential monitoring sites on a

regular basis. Some tourism operators, such as rafting guides may offer similar data collection opportunities.

Local conservation organizations such as Skeena Watershed Conservation Coalition, and SkeenaWild Conservation Trust currently participate in direct research and data collection. They also support First Nation fisheries programs collecting information related to the indicators recommend in chapter 5 (SkeenaWild, 2012; SWCC, 2012). Such organizations may be able to help First Nations, community groups, and fishing guides access resources to expand monitoring efforts. Possible activities include purchasing equipment, sponsoring data collection training programs, coordinating efforts, and assisting with access to remote locations.

Several local, provincial, and US academic institutions have taken an interest in Skeena salmon and habitat (see section 6.1). UBC is involved in the C-CAP climate change modeling project, which involves ongoing data collection (CCAP, 2012). Opportunities for collaboration should be explored. SFU has expressed interest in setting up a fresh water ecology research lab in the watershed, and are interested in assisting with data collection and capacity building (Moore pers comm.).

7.5.2 Training, Equipment, and Data Sharing

Participants will require data collection training, equipment, and the ability to upload their data to the watershed data management and sharing system (Bonney et al, 2009). Expert and on-site training are the most effective to ensure sampling techniques are developed that adhere to data collection standards (Dickinson et al, 2010). Consultants, government personnel, and academic researchers can support training through data collection courses and mentoring activities. Participants interested in

biomonitoring will be required to take an online course offered by Environment Canada in conjunction with field training (Environment Canada, 2011a). There may also be opportunities for training support through the BC Lake Stewardship Society (BCLSS, 2012), who already assist local groups such as the Lakelse Stewardship Society, Lake Kathlyn Protection Society, and the Pacific Streamkeepers Federation.

To maximize monitoring opportunities for the groups outlined above, a monitoring program should consider investing resources in training. Capacity building will also require access to equipment. A monitoring program should consider purchasing and lending monitoring equipment such as water sampling kits, conductivity meters, data loggers, and biomonitoring sampling tools.

Taking advantages of opportunities to build monitoring capacity will take time. It is important to get the proper governance structures and program capacity in place before pursuing the data collection capacity building outlined above.

7.6 Using Indicators to Assess Habitats

Program participants (informed by technical experts, WSP Habitat Working Group recommendations, and the scientific literature) need to agree on a process to use a suite of indicators to assess habitat status and trends (Jorgensen et al., 2005). This information can then be used to assess effectiveness of policy and planning implementation (WSP, LRMP's etc) (ILMB, 2007). Below is a six-step process for using the indicators recommended in chapter 5 to assess salmon habitat status (figure 3). The process is informed by ecosystem based management implementation in the Great Bear Rainforest (CIT, 2004), an effectiveness monitoring program in the Babine watershed (BWMT, 2011), Wild Salmon Policy implementation strategies (DFO, 2005),

and United States Department of Agriculture effectiveness monitoring design and implementation recommendations (USDA, 1999).

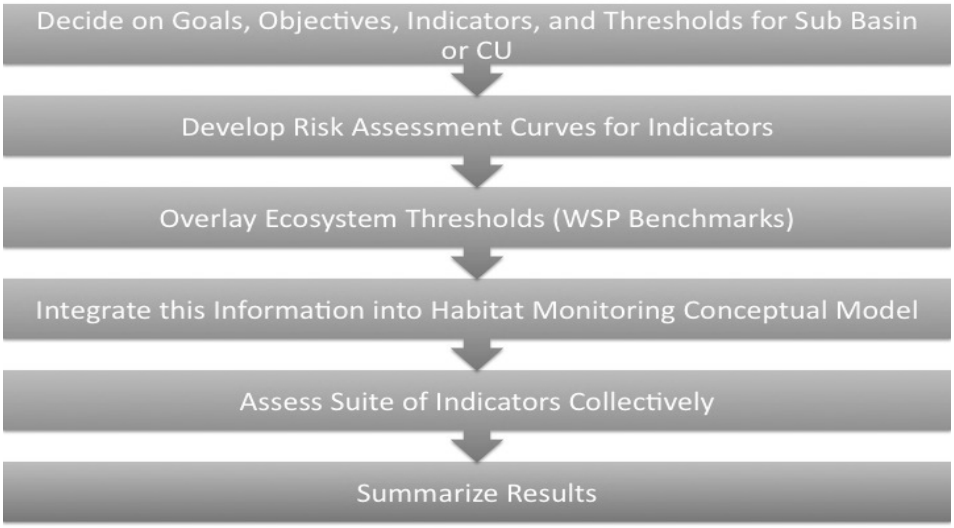

Figure 3: Process for Using Indicators to Assess Habitats

7.6.1 Goals, Objectives, Indicators and Ecological Thresholds

Goals and objectives should be articulated for a specific sub basin or CU using the pressure analysis, habitat status reports, and monitoring mapping described in section 7.4. Once goals and objectives have been agreed upon, a suite of indicators can be chosen which inform whether those goals and objectives are being put at risk (Price & Daust, 2009). Indicators must be applicable to the species, life history phases and habitat types specific to the geographic area of interest (Stalberg et al., 2009). A sub-set of the chosen indicators should inform impacts from climate change, and existing or proposed developments specific to that sub-basin. Thresholds and risk assessment curves for indicators may vary depending on the type of ecosystem and species being monitored, and indicator being used (Price & Daust, 2009; Nelitz & Wiekowski, 2011).

7.6.2 Developing Risk Assessment Curves

Increasingly, monitoring and cumulative effects assessments are using risk assessment curves to assess land use impacts on valued ecosystem components such as fish and wildlife (Price & Daust, 2009; NEI, 2005). For our application, risk assessment curves provide a visual analytical tool to help us understand how salmon respond to changes in habitats by representing the level of risk over a range of values for each indicator. Risk curves also provide insight into the likelihood of meeting a specific objective. For example, if the temperature of a specific stream or river does not exceed 15 ^{o}C when adults are present, we have a high degree of confidence that the risk of adverse effects associated with high water temperatures, such as pre-spawn or disease mortality, will be low (figure 4). As another example, if we keep road densities below 0.4km per km^2 in a specific sub-basin, we will have a high degree of confidence that the impacts from road development (a major influence on sediment inputs, fish passage issues, etc.) on salmon will be minimal.

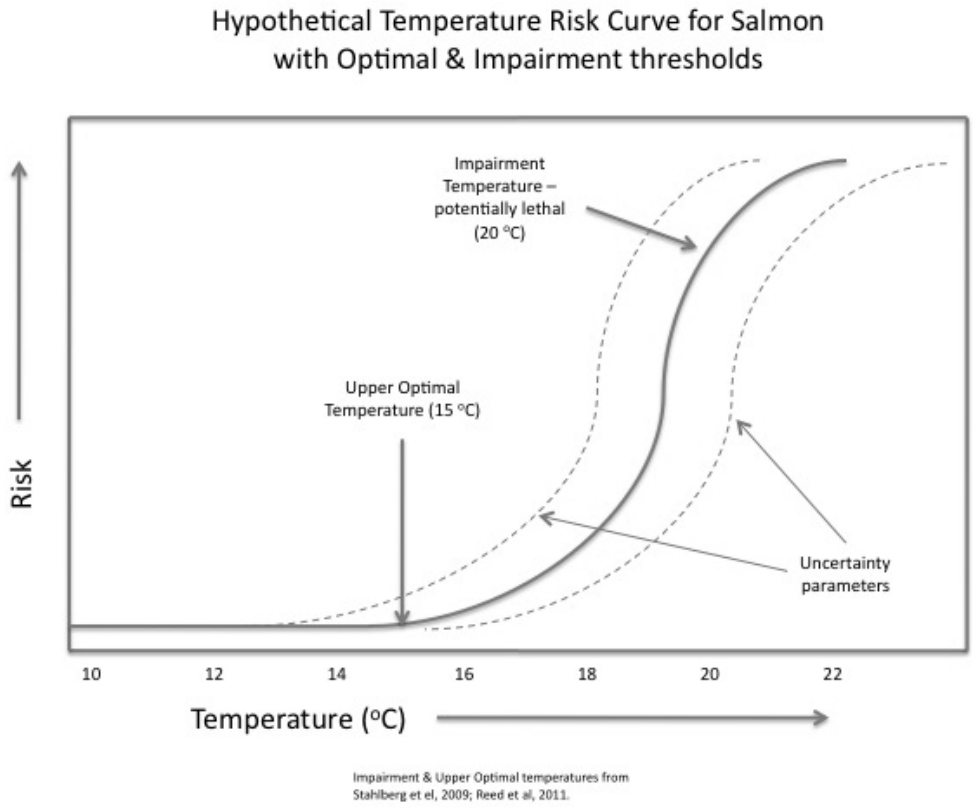

Figure 4: Hypothetical Risk Curve for Salmon (developed from Stahlberg et al., 2009; Reed et al., 2011)

Uncertainty around the risk curves and thresholds can be incorporated into the analysis by drawing distribution parameters around the median risk curve (Price & Daust, 2006; 2009). It should be noted that risk assessment curves for a specific indicator might vary by habitat type (e.g. road density impacts in coastal vs. Nechako plateau habitats). Therefore, multiple risk assessment curves may be required for a specific indicator within a particular sub-basin, or the Skeena as a whole. Further, developing risk assessment curves for some indicators may not be possible due to a lack of understanding of how salmon react over a range of values for that indicator.

Technical expertise exists in the watershed to draft risk assessment curves for many of the indicators recommended in Chapter 5 (Price & Daust, 2009; Daust pers comm.). Once drafted, risk curves can be peer reviewed and modified for use in assessing monitoring information under the program. Risk assessment curves for some of the indicators recommended in chapter 5 will be developed under the BVRC cumulative effects project (Morgan pers comm.).

7.6.3 Overlaying Ecosystem Thresholds (WSP Benchmarks)

Ecosystem thresholds (WSP benchmarks) defined in the scientific literature, recommended by the WSP habitat-working group, and defined by local expertise can be overlain on the risk assessment curves (see figure 4 – upper optimal & impairment temperature threshold examples). This information will strengthen the ability to assess monitoring information, and can potentially be used to set trigger points for management action. Setting thresholds can be applied directly from the WSP Habitat Working Group Recommendations and scientific literature, or modified for local application by technical experts. Thresholds can also be modified, informed by status and trend monitoring information for specific sub-basins and CU's (Wiekowski, 2011).

7.6.4 Developing Habitat Monitoring Conceptual Model

Development of a conceptual model will assist in linking monitoring goals and objectives for a specific sub basin or CU to the indicators and ecosystem thresholds required to assess whether those goals and objectives are being met (Price & Daust, 2009). An example of a hypothetical high-level habitat monitoring conceptual model is presented below (figure 5), showing the relationships among goals, objectives, and

strategies (represented by targets and threshold values of implementation indicators) for protecting Babine sockeye habitat.

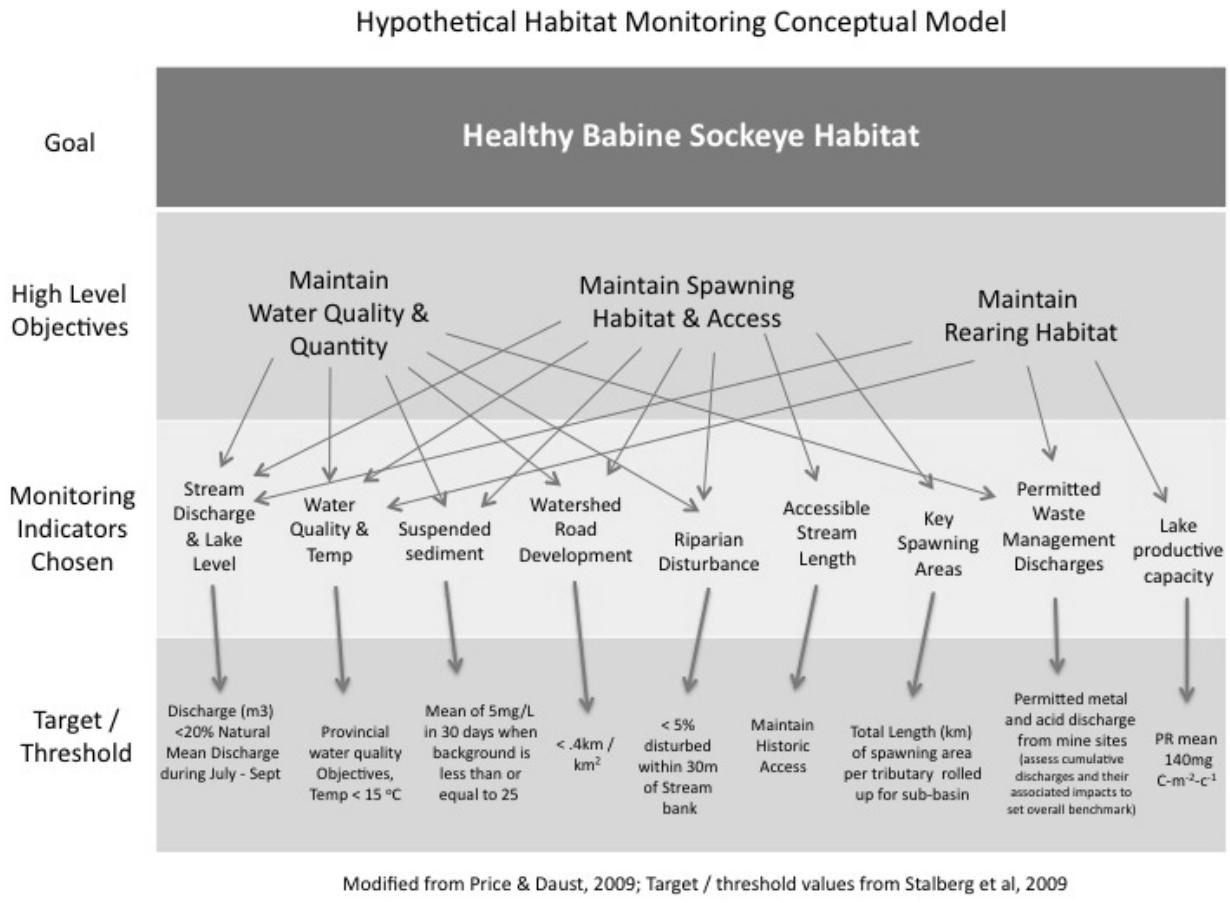

Figure 5: Hypothetical Habitat Monitoring Conceptual Model (modified from Price & Daust, 2009; threshold values from Stalberg et al., 2009)

7.6.5 Assessing Suite of Indicators

Assessment matrixes, probability analyses, and scoring systems provide methods for assessing risk and status using monitoring results for a suite of indicators chosen for a sub-basin or CU (Pastakia, 1998; Sutter, 2007; Paul & Munns, 2011).

Assessment Matrix

Assessment matrixes are a common and somewhat subjective way of analyzing a suite of habitat indicators to assess the overall status or risk to a habitat or CU by collectively defining monitoring results for the indicators against their risk curves and thresholds (Pastakia, 1998; Daust pers comm.). This approach is used in the Coastal Watershed Assessment Procedure, which lists the risks associated with all of the indicators in a table (MOF, 1995). The risk table is then used by experts to subjectively assess the overall risks to a watershed. The assessment process can be relatively straightforward if the indicators are independent from each other. If there is a lot of overlap in the indicators, the process is more complex (Daust pers comm.).

For larger watersheds or CU's it may be necessary to assess indicators at finer scales (by spawning / rearing tributary for example) to properly assess the overall habitat status or risk. This will help identify specific areas of concern requiring further monitoring and analyses. Consideration should also be given to defining status ratings for specific tributaries or habitat for subpopulations or life history stages within the CU.

Probability Analysis

A probability analysis uses mathematical probabilities of reaching the objective from the indicator risk curve analyses (Paul & Munns, 2011; Price & Daust, 2009). The probability numbers for each indicator are multiplied to get a cumulative probability of reaching the objectives (as outlined in the habitat impact conceptual model).

Probability analyses are conceptually useful, and can be a theoretically sound way of combining risks from monitoring data for multiple indicators. Uncertainty in the probability can make the analysis difficult, however, and large uncertainty parameters

for multiple indicators can weaken results (Benke et al., 2007). It is also difficult to weight the level of risk associated with each indicator in a probability analysis. Further, the chosen indicators may be too limited to assess all of the impacts on salmon habitat in that specific area – making an exact measurement difficult.

Scoring System

A third method for analyzing monitoring data for multiple indicators is to weight each indicator differentially by assigning a scoring system (Talberth et al., 2010; Paukert et al., 2011). This system sums the individual risk scores for each indicator and uses to total score to estimates the overall risk to the CU or watershed. Indicators with greater causal relationships and adverse effects for the species and life history stage of interest should be scored higher than those, which indicate a lesser impact (Nelitz et al., 2007b).

Assessing a suite of indicators is a difficult and inexact process, and there is currently no widely accepted method to aggregate indicator data to define watershed status (Pickard et al., 2008). The methods described above are simply examples of different approaches that can be used to assist the process, many others approaches exist (Sutter, 2007). Regardless of the method chosen, it is important to interpret the level of risk associated with the monitoring results from each individual indicator, and to try to understand the cumulative risks for the suite of indicators being assessed. The level of risk tolerance for specific CU's or watershed is a value judgment and will depend on the cultural, economic, and ecological importance of the area or CU (DFO, 2005). Defining risk tolerance prior to monitoring reduces bias in interpreting results (Burgman, 2005), and should be considered during program design, and prior to analyses.

7.6.6 Summarizing Results

Understanding and protecting salmon habitat using freshwater habitat monitoring information and analyses is one of three important components to protecting salmon. Harvest information, risks and status information being assessed under WSP strategy 1, and marine ecosystem information on ocean conditions and its implication for productivity being assessed under WSP strategy 3 need to be integrated to inform decision making (WSP, 2005). Developing a larger monitoring conceptual model combining all of this information can assist in understanding the monitoring needs and health of salmon originating from a particular sub-basin or CU (Daust pers comm.). Further, information on threats from climate change, proposed development, and natural disturbance events are also important to incorporate (Stalberg et al., 2009). There may be opportunities to use this information to undertake detailed cumulative effects analyses, similar to what is currently being carried out by the Bulkley Valley Research Center for the Morice sub-basin (BVRC, 2011).

7.7 Communicating Results

Results from ongoing monitoring and analyses should be communicated directly to First Nations, and government agencies involved in land use decisions in the watershed. It is important that individuals connected to provincial, federal and First Nation governments be involved in the program (Creech, 2001). Such participants provide important communications linkages to senior managers and leadership to help ensure the resulting information is incorporated into decision-making.

Communicating to the public and interest groups is also important and has the potential to increase local stewardship. A monitoring program website, annual state of

the watershed reports, and press releases offer effective ways of delivering information, and increasing interest in the program (IAN, 2012).

Informing funders of the value and effectiveness of the program requires on-going targeted communications (Bothwell, 2000). Program impacts on knowledge of habitat status, trends, and cumulative impacts from development and climate change will be of relevance. Funders may be particularly interested in the program's success in strengthening relationships amongst participants, and linkages to improved resource management decision-making.

Beyond external communications, it is important to provide information to participants within the program. This helps keep participants engaged and helps create a sense of accomplishment (Donald, 1997). Developing a detailed communications plan at the outset of the program to implement information exchange and reporting is significant to program success (Lefler, 2010)

7.8 Management Integration

Beyond communication, monitoring information and analysis can provide critical information to assess whether regional land use plans, and policy, such as the WSP, are meeting their objectives (Hammond et al., 1995). For example, effectiveness monitoring programs such as the Babine Watershed Monitoring Trust (BWMT, 2012) can use the resulting monitoring information to assess the effectiveness of land-use plans for meeting objectives related to salmon and habitat in the Babine watershed. Government, industry, and ENGO's can also initiate effectiveness assessments using the resulting information. Some indicators may also provide useful information to assess wildlife and water quality objectives in land use plans (ILMB, 2007).

A salmon habitat-monitoring program, as recommended by this project, would fulfill several WSP strategy 2 implementation requirements (DFO, 2005). Action steps 2.2 (select indicators and develop benchmarks for habitat assessment), 2.3 (monitor and assess habitat), and 2.4 (establish linkages to develop and integrated data system for watershed management) are all key components of this project - providing a strong link to federal management of salmon and habitat. Incorporating this information into a strategic planning process (WSP strategy 4), if developed, would further strengthen management integration at the federal level.

Habitat status reports, pressure analyses, and monitoring reports from the program will provide essential information for developing salmon recovery plans, as mandated by the WSP and Marine Stewardship Council (MSC) fisheries certifications. Both the WSP and MSC require the implementation of rebuilding plans for CU's found to be below their lower benchmark or limit reference point (WSP, 2005; Moody Marine, 2010). Recovery plans will inform adaptive management approaches to sub-basin restoration and CU recovery.

Monitoring information and analyses from the program can also be used to assist Skeena First Nations in managing resources. Delivering information through presentations and reports tailored to First Nation interests around CU's of food fish interest can strengthen the programs effectiveness. Assisting First Nations in integrating monitoring data into their GIS, mapping and monitoring programs can further enhance their ability to assess land use impacts and development proposals (Salmo Consulting Inc. et al., 2004). Involving First Nations in program design and implementation will help strengthen such management linkages.

7.9 Capacity Requirements

Acquiring capacity to coordinate efforts, manage data and monitoring efforts, and manage resources is a common feature of successful monitoring programs (Creech, 2001). If resources permit, creating a secretariat or coordinator position should be considered to help set up and run the program. Responsibilities could include:

- Managing the flow of monitoring information;
- Keeping participants engaged;
- Consulting with participants and managing delivery on work plans;
- Managing finances & fundraising.

Coordinating skills and some knowledge of salmon biology and data management are important qualifications to consider for such a role. Other habitat monitoring efforts have failed because of a lack of capacity and reliance on volunteer efforts (Lindenmayer & Likens, 2010).

Resources to set up a data-sharing network and to hold workshops to design, implement, and manage the program are also important. Resources and governance requirements to enable program capacity are discussed in chapters 8 and 9.

CHAPTER 8 – PROGRAM GOVERNANCE & STRUCTURE

Designing appropriate governance structures and monitoring frameworks are fundamental to establishing effective environmental monitoring programs (Pilz et al., 2005; Creech, 2001; Conrad & Daoust, 2008). This section explores potential governance structures used in collaborative monitoring programs throughout North America for their application to the program. Monitoring frameworks are also discussed to assist in designing and guiding data collection and analyses.

8.1 Governance Overview

Governance is the formalization of the relationships among participants, includes mechanisms for accountability, and details the decision making structure (IISD, 2012). Developing a governance structure early in the process of initiating a collaborative monitoring program may be challenging. Governance needs to flow from discussions among participants on how the program will operate, what its goals and objectives should be, and how to achieve those most effectively (IISD, 2012).

Important components of a monitoring program governance structure include:

- Vision, mission, goals and objectives (what is the monitoring program all about?);
- Decision making process (types of decisions the participants, board, managers, and staff have the authority to make);
- Partnership principles (operating values that guide collaboration);
- Membership arrangements (who participants are);
- Duties and responsibilities of participants (what is expected of the participants);
- Accounting and reporting (how the program and its participants communicate its work and financing to the broader community);

- Other issues of concern (i.e. role of the secretariat and technical comities, data collection / training, purchasing and lending monitoring equipment, dispute resolution, limitations on advocacy positions / public statements etc.).

Setting up a governance structure for a collaborative monitoring program often takes one of two forms. Participants may set up a monitoring network governed by a formal agreement for cooperation, such as a contract or memorandum of understanding. Monitoring networks usually assign core members as a governing council of the whole (Creech, 2001). The organization, which initiates and sets up the monitoring network, typically retains the role of managing the alliance.

The second governance approach is for the member organizations to create an autonomous legal entity. Establishing a legal entity, such as a society or trust, offers the benefits of creating a mechanism to raise and manage funds, and a lasting institutional structure for the program (Pilz et al., 2005). Many collaborative monitoring programs operate as non-profit charitable organizations (legal entity) made up of a volunteer board, manager, staff, and members (Causton, 2008). The formal mechanism for how these individuals carry out their responsibilities vary greatly, but in general, the board provides the overall strategic direction for the program, the director or manager is responsible for implementing the strategic plans, staff are responsible in assisting the director in carrying out the programs work, and members are responsible for assisting with gathering and managing data, identifying data gaps, and communicating information resulting from the program to their constituents, decision makers, and the public (Causton, 2008). There is some concern that setting up a new organization may focus too much attention inward on the organization itself, instead of outward to those it

wishes to engage. This could diminish the network advantage of joint value creation, capacity building, and policy links (Creech, 2001). If it is decided to set up a new organization for the program, such concerns should be considered and mitigated during governance design.

Another important component of monitoring program governance structures is the role of sponsors (Pilz et al., 2005). Sponsors are organizations that give long-term support to the program through financial and in-kind donations. In addition to funding, sponsors such as government agencies, academic institutions, and NGO's can provide administration, technical and peer review, coordination, and logistical support to the program.

8.2 Examples of Collaborative Monitoring Governance Structures

Collaborative (also known as multi-party) environmental monitoring programs are some of the most successful types of ecosystem monitoring initiatives in North America (Conrad & Hilchey, 2011; Lefler, 2010). Below are governance structure overviews of three effective collaborative environmental monitoring programs. The Community Based Environmental Monitoring Network uses an informal partnership structure, the Pacific Northwest Aquatic Monitoring Partnership uses a formal partnership structure, and the Babine Watershed Monitoring Trust uses a non-profit organization structure (CBEMN, 2012; PNAMP, 2012; BWMT, 2011).

8.2.1 Community Based Environmental Monitoring Network (CBEMN)

The CBEMN was formed to set up a formal relationship between Saint Mary's University and community groups performing environmental monitoring in Nova Scotia. The primary role of CBEMN is to increase environmental monitoring capacity in Nova

Scotia by assisting with monitoring, providing training, lending equipment, and providing technical assistance in accessing and analyzing data for community groups, ENGO's, and individuals. The network is governed by an advisory committee made up of professors, professionals, students, community group members, and consultants, and is housed within the Saint Mary's University Geography Department (CBEMN, 2012). CBEMN also has sponsors and affiliate organizations.

8.2.2 Pacific Northwest Aquatic Monitoring Partnership (PNAMP)

The PNAMP is an alliance to coordinate monitoring activities and develop common monitoring approaches in Washington, Oregon, and Northern California with a primary focus on salmon watersheds. Membership includes government agencies, industry, and tribal groups with an interest in coordinating monitoring of watershed condition, fish populations, and restoration project effectiveness (PNAMP, 2012). The partnership is governed by a charter, which formalizes structure and participation, business practices, and reporting. The PNAMP decision-making structure includes executive partners, who provide policy direction to the steering committee. The steering committee (consisting of an appointee from each executive partner) is responsible for forming working groups to perform tasks consistent with PNAMP's principles (PNAMP, 2012).

8.2.3 Babine Watershed Monitoring Trust (BWMT)

The BWMT is a monitoring program that assesses the effectiveness of land use plans approved for the Babine watershed (BWMT, 2011). The BWMT is a non-profit charitable organization governed by a Trust agreement, which provides a legal device to insulate monitoring science from political and value judgments (Overstall pers comm.).

The Trust agreement details a process to define monitoring questions and provide impartial answers. Trustees are legally bound to follow the Trust agreement as opposed to personal or politically influenced preferences (BWMT, 2011). The BWMT also uses a decision-making framework to impartially rank land use plan objectives that are most at risk of not being achieved. The combination of the governance structure and ranking methodology has succeeded in insulating the selection of monitoring projects, and the communication of their results from the influence of specific interest groups (Overstall, 2008).

8.3 Monitoring Framework

Beyond formalizing a governance arrangement - which details participant relationships, mechanisms for accountability, and decision making structure - it is important to agree on a framework describing how monitoring will be undertaken (Conrad & Daoust, 2008). Monitoring frameworks are typically designed for their specific application, but most follow the general approach of setting the question, designing a monitoring approach to answer the question, collecting data, and analyzing and interpreting the data. Adaptive monitoring incorporates a feedback loop by using the resulting analysis and interpretation to possibly reframe the question, and to adapt the monitoring approach (Ringold et al, 1996). To improve the effectiveness of monitoring programs, it's recommended that the monitoring framework address well-defined and tractable questions, incorporate rigorous statistical design, be based on an ecosystem conceptual model of how an ecosystem might function, and be driven by a human need to know about an ecosystem (Lindenmayer & Linkens, 2009; SWGSRO, 2002).

For the purposes of this program, the monitoring framework may be somewhat general compared to more focused research or effectiveness monitoring initiatives. Status and trend monitoring for Skeena salmon habitat is quite broad, and data acquired from the various sources outlined in chapter 7 can be used to assess the system on a large scale without implementing focused monitoring. The framework will then need to incorporate a method of implementing more detailed monitoring of high priority areas where increased field based sampling will be required (see section 7.4) (Stalberg et al., 2009). Ongoing analysis at a broad level, and for high risk CU's, will also need to be included in the monitoring framework to assess trends in habitat health over time. The following framework (figure 6), developed for DFO's strategy 2 WSP implementation, is particularly relevant to the program (Wieckowski, 2011).

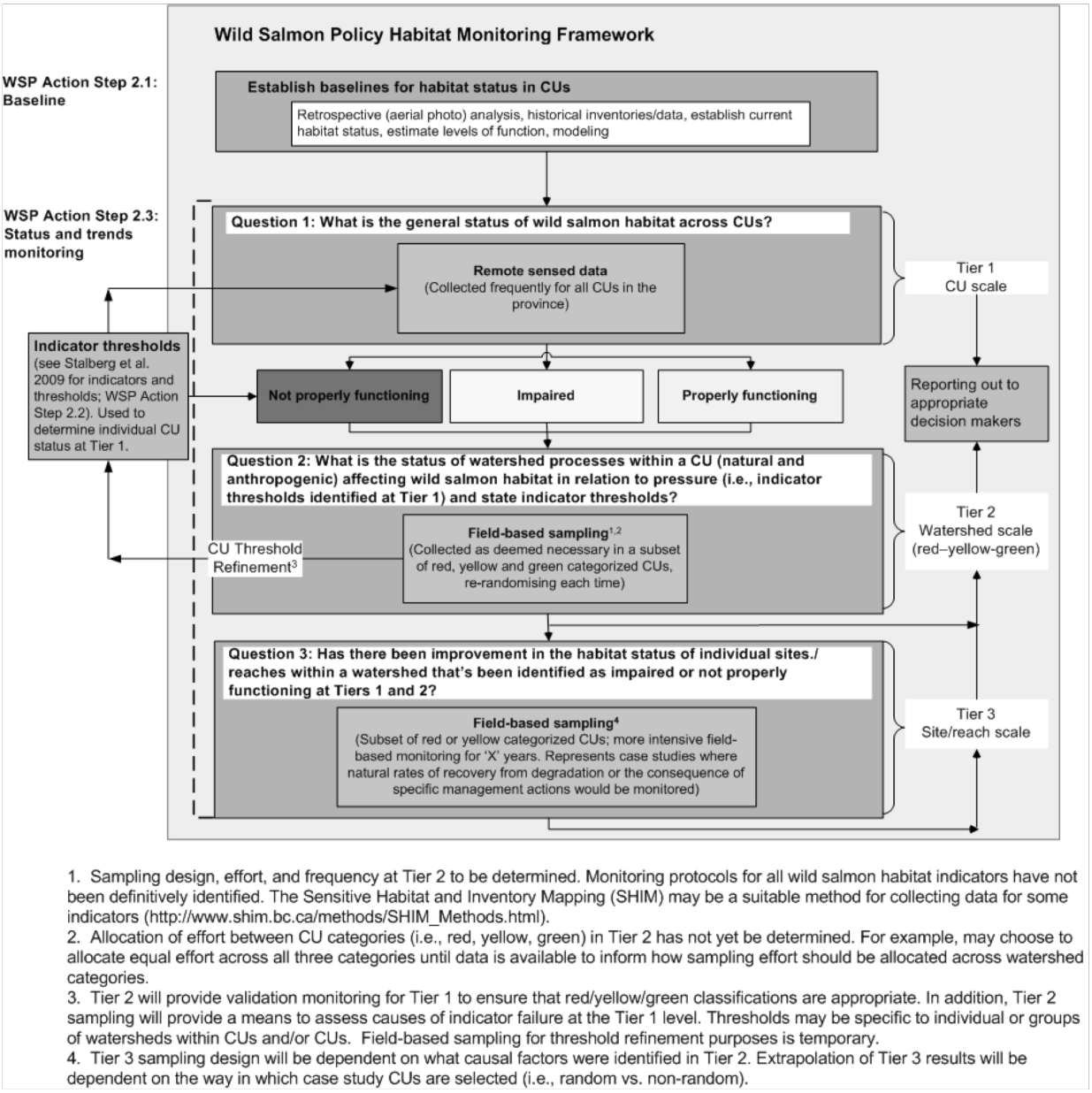

Figure 6: Wild Salmon Policy Habitat Monitoring Framework (Wieckowski, 2011).

The WSP strategy 2 framework partitions monitoring into three tiers (shown as questions in figure 6) to guide different levels and intensities of monitoring, depending on pressure analyses and restoration interests:

- Tier 1 uses pressure indicators (remote sensing) to assess the general status of habitats across CU's and designate them as properly functioning, impaired, and

not properly functioning. Categories will be assigned using indicator threshold values and scientific judgment. This is similar to the pressure analysis process recommended under section 7.4 – *Prioritizing Monitoring.*

- Tier 2 uses a suite of state indicators to examine the status of watershed processes within a CU affecting salmon habitat in relation to pressure and state indicator thresholds. Tier 2 is consistent to the recommendations outlined in section 7.6 – *Using Indicators to Assess Habitats.*
- Tier 3 uses pressure and state indicators to assess trends in habitat status for not properly functioning CU's over time. A specific purpose of this monitoring tier is to assess whether management actions, including protection, restoration and enhancement are showing improved habitat quality. The tier 3 objectives are consistent with the objectives proposed in this project - assessing trends in habitat health, adaptive management and rebuilding plan success.

Program participants should assess whether the WSP Strategy 2 monitoring framework outlined above can be modified to meet the needs of a Skeena monitoring program. Regardless of the monitoring framework chosen, focusing monitoring resources and analyses on habitats and CU's at highest risk (Stalberg et al., 2009), and incorporating feedback (adaptive monitoring) (Lindenmayer & Likens 2010), should be considered in framework design.

8.4 Governance Recommendations

Deciding on an effective governance structure for the monitoring program will require consultation with interested participants, and is worth considerable investment (IISD, 2012). Organizing participants' activities and relationships can be complex, but

developing focused goals and objectives that resonate with participants at the start of the process can simplify the arrangement. It is also important to involve as many of the key monitoring groups as possible in developing the governance structure to provide a broad sense of ownership and engagement (Creech, 2001).

The program outlined in this thesis will require considerable resources to implement, and a funding structure will be necessary to acquire financing and carry out work. An existing non-profit organization, such as an academic institution or ENGO could be used to house the program; however, this would require an entity with strong capacity and motivation (Pilz et al., 2005). It may also weaken the programs optics of collaboration and longevity, depending on the organization. A more favorable option may be to set up a non-profit organization such as a trust. The BWMT provides a useful example of how such an agreement could work, and how structures can be put in place to minimize bias and focus decision-making (BWMT, 2011). A trust would also create a mechanism for receiving charitable funding. Using a monitoring framework similar to the WSP habitat-monitoring framework (figure 6) would further assist in focusing and structuring monitoring efforts in an effective manner. Modifying this framework for application within the program should be considered.

CHAPTER 9 – RESOURCE REQUIREMENTS & OPPORTUNITIES

One of the key hurdles in implementing collaborative monitoring is accessing the necessary resources (Sharpe & Conrad, 2006). This section explores the resources required to implement and operate the program, and identifies potential funding sources and sponsorship opportunities.

9.1 Minimum Resource Requirements

Setting up a program so that it can run on little or no annual financial contributions can help enable an adaptive approach to a potentially erratic funding environment (Causton, 2008; Overstall, pers comm.). One way to achieve this is to found the core of the decision making structure on a volunteer board consisting of diverse interests, who are willing to provide long-term commitment and a small amount of volunteer time. Combining a dedicated volunteer board with a few good sponsor organizations to assist with administration, monitoring, and analysis can provide a strong foundation, longevity, and stability with minimal monetary resources (Savan et al., 2003; Causton, 2008).

From this base, funding resources accessed by the monitoring program can be dedicated to the highest priority areas with the assistance of a focused monitoring framework (such as that described in section 8.3). This means that in years of low funding, only the very highest priority habitats will receive monitoring and analyses through the program. In years of higher funding, there may be sufficient resources to monitor some areas of moderate priority (similar to approach taken by BWMT). Other related existing government, First Nations, and community monitoring will continue

outside the program. These monitoring activities will provide additional data, which can be used by the program (if pertinent), regardless of direct funding availability.

Adding further capacity will require steady sources of funding, and strong and diverse sponsors. Components requiring resources consistently identified in interviews and the literature include; hiring a part time coordinator, setting up and managing a data system, designing a governance agreement, building a web site, analyzing pressure and state indicators, data collection, and administration (SWGSRO, 2002). Resources acquired in excess to these core expenses can be put into increasing monitoring, and analysis in identified priority areas. Below is an example of a basic implementation and operating budget (table 2; table 3). Some of these expenses may be reduced by in-kind donations from participant organizations. There may also be other unforeseen efficiencies depending on the capacity brought to the program by participants.

Year 1 Program Budget - *Program Development & Monitoring Costs*		
Program Development	Workshops	$3,000.00 (6 workshops * $500)
	Governance agreement	$1000.00
	Web site	$3,000.00
Coordinator	Salary (part time contract)	$18,000.00 (60 days * $300/day)
	Travel	$2,000.00 ($.50 / km * 4000km
	Office supplies / printing	$500.00
Data System	Set up	$5,000.00 (10 days * $500)
	Data input & administration	$5,000.00 (10 days * $500)
Data Analyses	Risk curve development	$4,000.00 (8 days * $500)
	GIS pressure Analyses (high priority CU's)	$10,000.00 (20 days * $500 / day)
	State indicator analyses (high priority CU's)	$10,000.00 (20 days * $500 / day)
Data Collection		$0
Administration (10%)		$6,150.00
Total		**$ 67,650.00**

Table 2: Sample Year 1 Program Development and Monitoring Budget.

Program Budget - *Annual Operating & Monitoring Costs*		
Program Support	Workshops	$2,000.00 (4 workshops * $500)
	Web site	$300.00 (domain & hosting)
Coordinator	Salary (part time)	$9,000.00 (30 days * $300)
	Travel	$1,000.00 ($.50 / km * 2000km)
	Office supplies / printing	$500.00
Data System	Data input & administration	$3,000.00 (6 days * $500)
Data Analyses	GIS pressure Analyses (high priority CU's)	$5,000.00 (10 days * $500)
	State indicator analyses (high priority CU's)	$5,000.00 (10 days * $500)
Data Collection		$20,000.00
Administration (10%)		$4,580
Total		**$50,380.00**

Table 3: Sample Program Annual Operating & Monitoring Budget

Hiring a part time coordinator is one of the larger expenses in implementing and operating the program as proposed. If finances are an issue, there may be opportunities to cover expenses of a person working within an existing participant organization who could undertake a coordinating role. Using such a person could reduce this budget item, especially if some of their time was offered as an in-kind contribution. Regardless, the above sample budget and ideas are offered as a starting point for discussions, and should not limit creativity around resourcing, implementing, and operating the program.

9.2 Potential Funding & Resources

Accessing funding for program implementation and annual monitoring costs is a significant challenge for the program (Sharpe & Conrad, 2006). Fortunately, there are fairly diverse funding options including, donations from members, sponsors, US and Canadian foundations, private donors, federal and provincial governments, and

industry. A resilient funding strategy requires diverse funding partnerships (Struthers, 2005; Connolly & Lukas, 2002), the following is an overview of potential opportunities and ideas.

9.2.1 Member Group Donations / Support

Below is a list of potential program participants who may be interested in providing a sponsorship role to the program. Such sponsors bring possible cash and in-kind donations through existing internal funding, capacity, and expertise.

As the Department of Fisheries & Oceans (DFO) has a specific Interest in WSP implementation (DFO, 2005), this program would help achieve the goals of strategy 2. DFO may be willing to assist with technical analysis, and covering some program expenses through existing habitat related funding.

BC Ministry of Environment (MOE) has expertise in water quality, quantity, biomonitoring, and GIS related indicator data collection and analyses (MOE, 2012). The ministry has expressed interest in the program (Sharpe pers comm.), and may be able to offer access to data, analyses, and data collection services to the program.

The Bulkley Valley Research Center (BVRC) currently provides administrative support to the Babine Watershed Monitoring Trust, and may be interested in providing similar service to the Skeena salmon habitat monitoring program (BVRC, 2012). BVRC is in the planning phase of implementing a data sharing system for the region (similar to that discussed in section 7.3), and have acquired responsibility for the Northwest Data Sharing Network. The program should explore whether such a data sharing system can be designed and implemented in collaboration with the BVRC that would fulfill the needs of the program. Data, analyses, and expertise developed under the BVRC cumulative

effects project could also be helpful in monitoring and assessing habitat. The centre has expressed interest in the program, sharing information, and creating collaborative arrangements to achieve common purposes. The BVRC also provides important linkages to cultural aspects of salmon monitoring, and potential collaboration with First Nations (Budhwa, pers comm.).

Pacific Salmon Foundation (PSF) has provided extensive support for WSP implementation in the Skeena, and to date has focused on strategy 1 and strategy 4 (SWI, 2012). PSF indicated that they have funding available to assist with strategy 2 implementation, and can potentially help with pressure and state analyses, and habitat impact reports. PSF has expertise with salmon habitat monitoring in the Fraser watershed, and may be able to provide resources to help set up the program, through hosting workshops and providing secretariat services during the development phase (Connors pers comm.).

SkeenaWild Conservation Trust has been working on WSP implementation in the Skeena for over five years, and is interested in helping implement a salmon habitat monitoring program to help meet the organizations conservation objectives (SkeenaWild, 2012). SkeenaWild has offered to assist with implementation, capacity building, ongoing monitoring, and the use of its existing monitoring information and analyses.

9.2.2 Foundation Grants

A number of US and Canadian philanthropic organizations currently invest in Skeena habitat conservation, and may be interested in supporting the program.

Tides Canada supports conservation organizations and First Nations salmon habitat protection programs (Tides Canada, 2012).

Royal Bank Blue Water Project provides funding to watershed protection and stewardship initiatives, and has recently funded non-profit organizations in the Skeena (RBC, 2012).

Gordon & Betty Moore Foundation has invested in Wild Salmon Policy implementation in the Skeena since 2007 as part of their Wild Salmon Ecosystem Initiative Program (Moore Foundation, 2012).

Wilburforce invests in regions directly adjacent to the Skeena watershed and the Great Bear Rainforest, is science focused, and has specific interest in improving data sharing (Wilburforce, 2012).

Swift Foundation has recently focused on Northwest BC as one of its major investment areas, and is funding restoration and preservation projects for wild salmon fisheries in the Skeena (Swift, 2012).

9.2.3 Government Grants

Environment Canada EcoAction Community Funding Program provides grants to community bases non-profits for protecting water and biodiversity.

Living Rivers is a BC provincial government funding initiative to create a legacy for the province based on healthy watersheds, sustainable ecosystems and thriving communities. The $21 million dollar fund has invested in Skeena steelhead monitoring projects in recent years (Living Rivers, 2012).

Habitat Conservation Trust Fund (HCTF) is a conservation surcharge on BC anglers and hunters that invests over $5 million annually in projects that maintain and

enhance the health and biological diversity of British Columbia's fish, wildlife, and habitats.

9.2.4 Industry

CN Rail, the mineral sector, forest companies, and BC Hydro all have an interest in corporate social responsibility, and may be able to provide existing monitoring data, data collection and monetary support for the program.

CHAPTER 10 – CONCLUSIONS & RECOMMENDATIONS

Salmon conservation is a stated priority of the federal and provincial governments, and habitat monitoring is recognized as an essential conservation strategy by governments, industry, and citizens throughout the western North Pacific (DFO, 2005; SWGSRO, 2002; PSF, 2009; Walters et al., 2008). Regionally, First Nations, interest groups, and communities support comprehensive salmon habitat monitoring, and all are working to protect and restore salmon diversity and abundance in the Skeena (BVRC, 2009). Integrating efforts and focusing monitoring on the highest risk areas and populations offers a pragmatic approach (Messer et al., 1991). The resulting data and analyses can help us understand current impacts and threats, identify high risk habitats, implement adaptive management, and improve planning and management to help meet our conservation objectives (DFO, 2005, Stalberg et al., 2009). The following is a summary of recommendations and a simple framework to inform implementation.

10.1 Summary of Recommendations

Chapters 5 through 9 offer detailed discussions on membership, choosing indicators, integrating existing data and capacity, data analyses, communication, management integration, capacity building, governance, and resourcing for the program. Recommendations contained in these chapters are summarized below.

Program Participation: existing monitoring capacity requires integration through the participation of key federal and provincial agencies (DFO, Environment Canada, MFLNRO, and MOE), and First Nations undertaking monitoring in the watershed. Securing sponsors, such as local conservation groups, community groups, and

academics, who can bring capacity and expertise to the program is also critical. Identifying and enabling individuals and organizations who can champion implementation should be an initial priority. Undertaking such ground work to gain interest and participation from the above organizations and individuals is a key step in the program concept and design phase.

Setting Goals & Objectives: participants should define clear objectives prior to program implementation that articulate the desired state or outcomes of the program. It is recommended that identifying and monitoring salmon habitats and populations at highest risk from current and proposed development and natural disturbance should be a primary goal of the program.

Choosing Indicators: a process for finalizing a suite of indicators and reviewing data sources should be undertaken with local experts. This process should be informed by the WSP Habitat Working Group recommendations, and review and recommendations of this project. Indicators for specific sub-basins, CU's, and life history phases can be chosen on a case-by-case basis from this suite.

Data Sharing, Collection & Storage: integrating existing and new data sources into a cloud storage system that is properly catalogued, easily accessible, and updated, should be a core component of the program. Criteria can be developed and agreed upon that outlines data management objectives to avoid compromising the effectiveness of the system. All participants should agree to adhere to government data collection standards for indicators. Participants can use existing peer review processes, or develop a standardized approach for indicators without well-established data collection standards. Adequate metadata should be required for all data collected under

the program. Sampling designs need to be developed with proper technical expertise to ensure precise estimates are obtained while minimizing costs. Some form of written understanding for data sharing should be developed during the design phase, and existing agreements need to be respected by program participants.

Prioritizing Monitoring: monitoring and analyses undertaken by the program should be prioritized to those areas of the watershed that are identified as highest risk (highest impacts, threats, fish values, where gaps exist). Local expertise, GIS Pressure analyses, and habitat status reports can be used to identify priorities. Mapping current and past data collection sites in the watershed can also be initiated to assess spatial data gaps for relevant indicators. These tools in conjunction with a monitoring framework (see section 8.3) can be used by the program to identify key monitoring gaps, and help prioritize where available capacity and funding is focused for field-based sampling.

Expanding Data Collection: the program should explore potential partnerships with organizations that have interest and ability to integrate data collection into their current activities. This will help expand the monitoring capacity of the program and minimize costs. Interest groups, government agencies, First Nations, community groups, ENGO's, and academic institutions offer a tremendous resource for expanding current monitoring capacity in an efficient and cost effective manner. The program should consider investing resources in training and equipment for participants that can assist in filling key data gaps.

Using Indicators to Assess Habitats: monitoring objectives should be articulated for a specific sub-basin or CU using the pressure analysis, habitat status reports, and

monitoring mapping described in section 7.4. Once monitoring objectives have been agreed upon, a suite of indicators can be chosen to inform the health and risks to the habitat, CU, and / or particular life history phase of interest. Risk assessment curves should be developed for the suite of indicators chosen by the program to inform the indicators' effects on salmon over a range of values. Ecosystem thresholds (WSP benchmarks), as defined by the WSP Habitat Working Group and scientific literature should be overlain on the risk assessment curves developed for each indicator to define when salmon are being put at significant risk. Developing a conceptual model will assist in linking monitoring objectives for a specific sub–basin or CU to the indicators and their associated ecosystem thresholds. Such conceptual models can help in understanding the relationships among objectives and strategies. Methods such as assessment matrixes, probability analyses, and scoring systems, can be used to interpret the overall risk and status rating of sub-basins and CU's from the collective results of the suite of indicators monitored. Defining risk tolerance for sub-basins and CU's helps reduce bias in interpreting results, and if possible, should be made explicit during program and monitoring design.

Communicating Results: participants connected to provincial, federal, and First Nations governments can assist by using their relationships with senior managers and leadership to communicate monitoring results and analyses. A monitoring program website, annual state of the watershed reports, and press releases are effective tools to deliver information, and increase interest in the program. It is also important that funders understand how the program strengthens relationships amongst participants, and enables improved resource management decision-making. Program participants need

to be informed on an ongoing basis of monitoring efforts and results. A detailed communications plan should be developed at the outset of the program to implement information exchange and reporting.

Management Integration: monitoring information and analyses should be used to implement Strategy 2 and develop linkages to Strategy 4 of the WSP, and assess the effectiveness of sub-regional land and resource management plans. The information will also be valuable in assisting First Nations in assessing proposed development and potential adverse impacts. Monitoring and analyses will also help in developing adaptive management approaches to sub-basin restoration and CU recovery plans.

Capacity Requirements: creating a secretariat or coordinator position should be considered to help set up and run the program. Responsibilities could include managing the flow of monitoring information, keeping participants engaged, and managing delivery on work plans and finances. Resources to set up a data-sharing network and hold workshops to design, implement, and manage the program are required.

Monitoring Framework: a monitoring framework should be designed early in the program to assist in focusing and structuring monitoring efforts. Modifying the WSP habitat-monitoring framework (figure 6) for application for the program should be considered.

Governance Structure: deciding on an effective governance structure for the program will require consultation with interested participants, and is worth considerable investment. Organizing participant's activities and relationships with each other can be complex, but developing focused goals and objectives that resonate with participants at the start of the process can simplify the arrangement. It is also important to involve as

many of the key monitoring groups as possible in governance design to provide a broad sense of ownership and engagement.

Resource Requirements: a funding structure is necessary to acquire financing and carry out work. An existing non-profit organization, such as an academic institution or ENGO could be used to house the program, though this would require an entity with strong capacity and motivation. A more favorable option may be to set up a non-profit organization such as a trust. The BWMT provides a useful example of how such an agreement could work, and how structures can be put in place to minimize bias and focus decision-making. A trust would also create a mechanism for receiving charitable funding.

10.2 Implementation Framework

Implementation requires informal and formal engagement with potential participants, with the goal of reaching agreements on structure and governance (Creech, 2001). These arrangements will then need to be formalized and implemented. A simple step-by-step process for implementing the program outlined in this project is offered below.

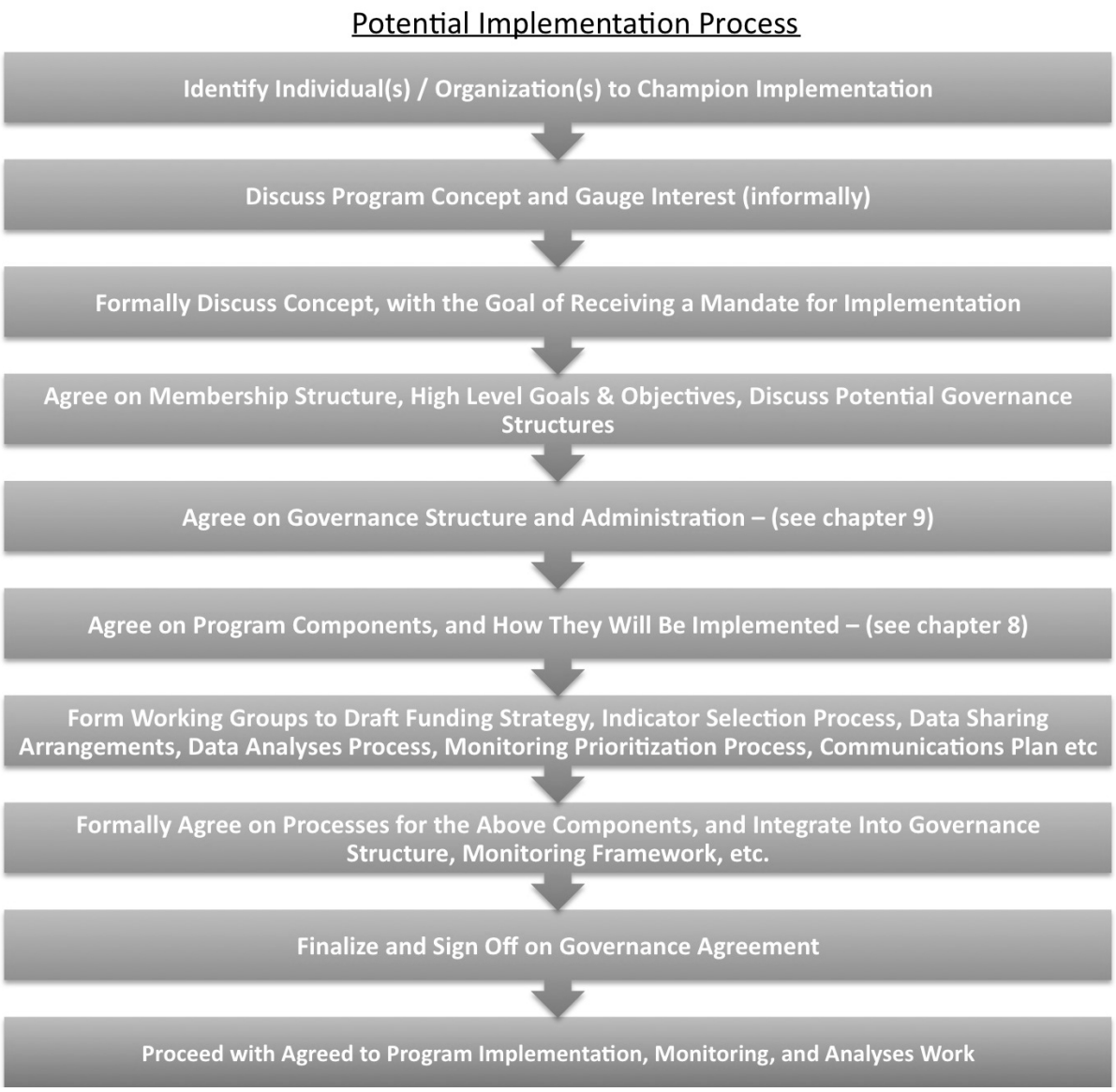

Figure 7: Potential Program Implementation Process

Last, and consistently highlighted as a key issue in the interviews, implementing a successful program requires finding a champion – organization(s) and individual(s) dedicated to doing the work and advocacy for development and implementation (Creech, 2001). Such a champion may exist in the list of potential sponsors provided in chapter 9.

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APPENDIX A – SKEENA HABITAT MONITORING BY SUB-BASIN

Lower Skeena Basin (below Zymoetz confluence)

Ecstall

Water Quality & Quantity Monitoring – DFO collected water temperature information just downstream from Ecstall Lake from 2000 - 2005. There is currently no water quality or quantity information being gathered in the watershed, except at the BC Hydro Falls River generating station. Flows and temperatures at generating sites are significantly altered and may not be representative of the rest of the Ecstall system.

Biomonitoring – there are no biomonitoring sites in the Ecstall watershed.

Pressure Monitoring – There are currently no major land use activities in the upper Ecstall watershed. Two small hydro generating stations, their associated reservoirs and power lines, and some forestry activity have relatively low impacts in the lower Ecstall. The BC Government holds data on cut blocks and forestry roads, while ENGO's (NWBC development monitoring) have data on the industrial water licenses, power lines, mining tenures / exploration, and forestry (appendix B).

Exchamsiks

Water Quality & Quantity Monitoring – The Water Survey of Canada has been operating a hydrometric station on the lower Exchamsiks River since 1962, collecting water level and discharge information.

Biomonitoring – There are no biomonitoring sites in the Exchamsiks watershed.
Pressure Monitoring – There are no industrial activities in the Exchamsiks watershed at this time.

Gitnadoix

Water Quality & Quantity Monitoring – DFO collected water temperature information from 2000 - 2005 on the Gitnadoix mainstem.

Biomonitoring – There are no biomonitoring sites in the Gitnadoix watershed.

Pressure Monitoring – The Gitnadoix watershed is designated as a Class A provincial park. There are no industrial activities in the watershed.

Lakelse

Water Quality & Quantity Monitoring – Environment Canada operated hydrometric stations collecting discharge data on the Lakelse River from 1948 – 1955, on Williams

Creek from1948 – 1954, and on Shulbuckhand Creek 1953 – 1955. Lakelse Watershed Society has collected water temperature, water level, and sediment data since 2003 from the Lake and several tributaries. DFO collected water temperature data on Sockeye, Clearwater, and Coldwater Creeks between 1994 and 1999. The UBC C-CAP project collected water quality, ecosystem, and fish passage information from 38 sites in Williams Creek, and the Lakelse main stem in May 2011, with more monitoring planned. The B.C. Ministry of Environment is currently conducting a multi-year sediment program on the Lakelse mainstem, Williams Creek, Scully Creek, and other small tributaries to the lake.

Biomonitoring – There are 7 biomonitoring sites in the Lakelse watershed located on the following tributaries - Sockeye Cr., Williams Cr., granite Cr., Furlong Cr., spawning Cr., killutsal Cr. Several of these sites also contain intermittent climate, hydrology, landscape, physical, substrate, and water quality (metals, nutrients, pH, DO, TSS, temp, etc.) data.

Pressure Monitoring – Vegetation modeling has been undertaken by UBC (C-CAP project) to analyze how different climate change scenarios could impact hydrology, carbon storage, forest composition, and the frequency of disturbances or extreme events. Forestry, and hydrology vector data are also available. Monitoring of current and proposed development has been undertaken by regional ENGO's (NWBC development monitoring). Vector layers available for the Lakelse watershed include; roads, clear cuts, water licenses, pipelines, and power lines.

Kalum

Water Quality & Quantity Monitoring – Environment Canada has operated a hydrometric station on Clarence Cr., a tributary of Kalum Lake, collecting discharge data since 1997. Two other hydrometric stations operated in the Kalum watershed, one on the Kalum River between 1928 and 1952, and the other on Deep Cr. from 1992 – 2009. Archived discharge data for these stations are available online at www.ec.gc.ca/rhc-wsc/default.asp?lang=En&n=894E91BE-1 . DFO collected water temperature information on Hadenschild Creek from 1994 – 1999.

Biomonitoring – There are six biomonitoring sites located in the Kalum watershed. These include sites on Clarence Cr., Luncheon Cr., Anweiler Cr., Cedar River, Deep Cr., and Spring Cr. Several sites include intermittent climate, hydrology, landscape, physical, substrate, and water quality (metals, nutrients, pH, DO, TSS, temp, etc.) data.

Pressure Monitoring – The UBC C-CAP project climate change, forest, and hydrology data are available for the Kalum watershed. Data available from the NWBC development monitoring includes; clear cuts, roads, power lines, mining, and water license layers.

Zymoetz

Water Quality & Quantity Monitoring – Environment Canada has operated two hydrometric stations in the Zymoetz watershed, one on the main stem near the Skeena from 1952 – 1964, and the second just below OK Creek from 1963 – present. DFO collected water temperature information from Hankin Creek from 1994 -1999. The Gitxsan Watershed Authority has monitored water temperature and level at the McDonell Lake outlet.

Biomonitoring – There are 17 biomonitoring sites located in the Zymoetz watershed, including; Trapline Cr. Treasure Cr., Copper R., 44km Trib, 51km Trib, Two Falls Cr., 49Km Trib., Coal Cr., Caribou Cr., Serb Cr., Sandstone Cr., Willow Cr., Passby Cr., and Silvern Cr. Most sites include intermittent climate, hydrology, landscape, physical, substrate, and water quality (metals, nutrients, pH, DO, TSS, temp, etc.) data.

Pressure Monitoring – The UBC C-CAP project climate change, forest, and hydrology data are available for the Zymoetz watershed. Data available from the NWBC development monitoring includes; clear cuts, roads, power lines, pipelines, mining, and water license layers.

Other

Biomonitoring – There is one additional biomonitoring site located on Thornhill Cr., which flows directly into the Skeena Main stem at Terrace.

Middle Skeena Basin

Kitwanga

Water Quality & Quantity Monitoring – The Gitanyow Fisheries Authority have collected water temperature and level data during annual operation of their smolt and adult salmon enumeration facilities since 2003. DFO collected water temperature data from Moonlit and Tea Creeks from 2000 – 2005.

Biomonitoring – There are two biomonitoring sites in the Kitwanga watershed, located on Tea Cr., and the Upper Kitwanga River. Both sites include intermittent climate, hydrology, landscape, physical, substrate, and water quality (metals, nutrients, pH, DO, TSS, temp, etc.) data.

Pressure Monitoring – Data available from the NWBC development monitoring include; clear cuts, roads, mining, and water license layers. Data may also be available from the Cranberry SRMP planning process (***ask Mark C)

Kispiox

Water Quality & Quantity Monitoring – Environment Canada has operated hydrometric stations on the Kispiox River since 1963, and Compass Creek since 1997. Both stations collect stream flow information. The Gitxsan Watershed Authority has collected water temperature and water level measurements for approximately 12 years at Clifford and Skunsnat Creeks. DFO collected temperature data from Cullen and Nangeese Creeks from 1994 – 1999.

Biomonitoring – There are 10 biomonitoring sites located in the Kispiox watershed. Sites include; Murder Cr., Compass Cr., Hevenor Cr., Date Cr., Canyon Cr., Cullon Cr., Helen Cr., Ironside Cr., and Steep Canyon Cr. 9 of the 10 sites include intermittent climate, hydrology, landscape, physical, substrate, and water quality (metals, nutrients, pH, DO, TSS, temp, etc.) data.

Pressure Monitoring – Data available from the NWBC development monitoring include; clear cuts, roads, mining, and water license layers.

Other

Water Quality & Quantity Monitoring – Environment Canada has operated 3 hydrometric stations on the main stem Skeena between the Babine and Zymoetz confluences, including; Skeena at Usk 1928 – present, Skeena at Gitsegukla 1960 -1971, and Skeena at Glenn Vowel 1960 – present. Currently, the Usk and Glen Vowell stations present real-time data (http://www.wateroffice.ec.gc.ca/text_search/search_e.html?search_by=p&region=BC).

Biomonitoring – There are 14 additional biomonitoring sites located on small tributaries, which flow directly into the Skeena Main stem below the Babine confluence. These include; Singlehurst Cr., Kleanza Cr., Hardscrabble Cr., Ascaphus Cr., Legate Cr., Little Oliver Cr., Fiddler Cr., Quill Cr., Insect Cr., Mill Cr., Pinenut Cr., Sterritt Cr., Shegunia Cr., and McCutcheon Cr. All of these sites include intermittent climate, hydrology, landscape, physical, substrate, and water quality (metals, nutrients, pH, DO, TSS, temp, etc.) data.

Upper Skeena Basin (above Babine confluence)

Slamgeesh

Water Quality & Quantity Monitoring – The Gitxsan Watershed Authority has recorded water temperature and level data at the Slamgeesh enumeration facility for the past 11 years. DFO collected temperature data from the Slamgeesh River from 1994 – 1999.

Biomonitoring – There are no biomonitoring sites in the Slamgeesh watershed.

Pressure Monitoring – There is no current or proposed development in the Slamgeesh watershed.

Skeena Above Sustut

Water Quality & Quantity Monitoring – Talhtan Fisheries has conducted water quality studies since 2007 at 4 sites in the upper Skeena. The data consist of physical attributes (dissolved oxygen, temp, conductivity, total dissolved solids, total suspended solids, anions and nutrients, organic carbon, and total metals). Current data logger (temperature & Level) sites exist on the main stem Skeena at Kluakaz and Otsi confluences, on Kluakaz and Otsi creeks, and on the Kluayaz at the Kluatantan confluence. The Gitxsan Watershed Authority has 5 data logger sites collecting temperature and level information at Tan Tan, Chipmunk, Biernes, Fort, and Currier Creeks. DFO collected temperature data from Kluatantan from 1994 – 1999.

Biomonitoring – There are 4 biomonitoring sites in the Upper Skeena, including; Beirnes Cr., Ethel Cr., Campbell-Johnson Cr., and Garner Cr. All of these sites include intermittent climate, hydrology, landscape, physical, substrate, and water quality (metals, nutrients, pH, DO, TSS, temp, etc.) data.

Pressure Monitoring – The Skeena above Sustut is almost pristine; however, there are several development proposals. Data available from the NWBC development monitoring includes; coal bed methane tenures, mining exploration, and rail line layers.

Sustut / Bear

Water Quality & Quantity Monitoring – Temperature and water level data have been collected at the BC FLNRO fence in the upper Sustut River since 1994 for their operating period of late July – end of Sept. DFO collected water temperature data on Asitka and Salix Creeks from 2000 – 2005

Biomonitoring – There are no biomonitoring sites in the Sustut / Bear watershed.

Pressure Monitoring – Data available from the NWBC development monitoring include; clear cuts, roads, mining, power line, and rail line layers.

Other

Environment Canada has operated a hydrometric station on the main stem Skeena just above the Babine confluence since 1970. Real-time data is available (http://www.wateroffice.ec.gc.ca/text_search/search_e.html?search_by=p&region=BC).

Babine Basin

Babine River

Water Quality & Quantity Monitoring – Environment Canada operates two hydrometric stations on the Babine River – one at Fort Babine with data from 1929 - present and the other at the outlet of Nilkitwa Lake (DFO counting fence) with data from 1972 - present. DFO collected water temperature from Nichyeskwa River and Onerka Lake from 2000 – 2005.). The provincial government (MoE) monitored sediment in relation to forestry and natural inputs in the Nilkitkwa and Nichyeskwa watersheds from 1992 – 1995 (Maloney, 1995, 1997). A comprehensive annotated bibliography of Fisheries, Water and sediment quality studies in the Babine Watershed can be found in De Groot (2004). The Babine Watershed Monitoring Trust undertakes effectiveness monitoring of land use plans in the Babine watershed, with most of its focus on the Babine River corridor. Several of its monitoring projects have collected water quality data in relation to road building and stream crossings (BWMT, 2011).

Biomonitoring – There are 15 biomonitoring sites in tributaries entering directly into the Babine River downstream of Nilkitkwa Lk. 13 of these are in the Nichyeskwa watershed, 1 in Gail Cr., and 1 in Cataline Cr. All sites include intermittent climate, hydrology, landscape, physical, substrate, and water quality (metals, nutrients, pH, DO, TSS, temp, etc.) data.

Pressure Monitoring – Data available from the NWBC development monitoring include; clear cuts, roads, and mining layers. Information related to forestry development impacts on fish habitat is available from the Babine Watershed Monitoring Trust.

Babine Lake

Water Quality & Quantity Monitoring – Environment Canada has operated several hydrometric stations on Babine Lake and tributaries. These include; Babine Lk at Topley Landing 1955 – present, Babine Lake at Smithers Landing 1972 – 1977, Babine Lk at Pendelton Bay 1972 – 1976, Twain Cr 1998 – present, Fulton River 1963 – 1970, and Pinkut Cr 1962 – present. Several limnological studies have been undertaken to investigate water and sediment quality in relation to mining discharges, and their impacts on aquatic and fish health. These include; Levy and Hall (1987), Stockner and Shortreed (1976, 1978), Hallam (1975), Chau and Wong (1975), Environmental Protection Service (1984,1990), Rescan (1992), Hatfield (1989), and Godin (1992).

Biomonitoring – There are 19 biomonitoring sites on tributaries that flow into Babine Lake. These include; Little Joe Cr., Guess Cr., Fedral Cr., Tattersall Cr., Tanglechain Cr., Tachek Cr., Pierre Cr., Twain Cr., Phantom Cr., Gullwig Cr., Pinkut River, Augier Cr., Lords Cr., Coldwater Cr., and Sutherland River. The 11 sites include intermittent climate, hydrology, landscape, physical, substrate, and water quality (metals, nutrients, pH, DO, TSS, temp, etc.) data.

Pressure Monitoring – The Bell and Granisle mines are monitored by the BC Ministry of Environment for metals, total suspended solids, sulphate, and benthic invertebrates, amongst other data. This information is used to assess metal leaching and acid mine drainage impacts in Babine Lake (Tamblyn pers comm). A summary of toxicity studies for the Bell and Granisle mines is found in Remington (1995). The report also contains information on potential future ARD, and metal leaching, and recommendations on monitoring requirements. Data available for the western portion of Babine Lake from the NWBC development monitoring include; clear cuts, roads, mining, power line, and water license layers.

Morrison / Tahlo

Water Quality & Quantity Monitoring – Environment Canada operated a hydrometric station on the Morrison River from 1965 – 1970. Pacific Booker Minerals collected baseline water quality information from Morrison and Nakinilerak Lk. from 2006 - 2008, and 2011 (Laidlaw, 2011).

Biomonitoring – There are no biomonitoring sites in the Morrison / Tahlo watershed.

Pressure Monitoring – Data available from the NWBC development monitoring include; clear cuts, roads, mining, power line, and water license layers. Detailed reports of potential impacts to fisheries values from the Morrison Mine project proposal are available from Environment Canada, and Babine River Foundation (Environment Canada, 2010; Overstall, 2010).

Bulkley Basin

Bulkley

Water Quality & Quantity Monitoring – Environment Canada operates six hydrometric stations in the Bulkley watershed downstream of the Morice River confluence. These include; Bulkley R. near Houston, Bulkley R. at Quick, Goathorn Cr., Simpson Cr., Telkwa R. below Tsai Cr., and Two Mile Cr. The Bulkley R. near Houston and Bulkley River at Quick stations provide real-time data. Discontinued stations include; Bulkley R. near Hazelton 1915 – 1952, Bulkley R. near Smithers 1915 – 1971, Kathlyn Cr. 1967 - 1979, Kathlyn Lk. 1968 – 1980, and Canyon Cr. 1973 – 1998. DFO collected water temperature data from Glacier Gulch Cr., Kathlyn Cr., Telkwa R. and Elliot Cr. from 2000 – 2005, and from Toboggan Cr., and the Telkwa R. from 1994 – 1999. The provincial government has set site-specific water quality objectives for the Bulkley River Watershed, and has monitored coliforms, turbidity, suspended solids, total residual chlorine, chlorophyll a, nutrients, and dissolved oxygen since 1986 (Nijman, 1986). Toboggan Creek has been sampled by the provincial government since 1996 for nutrients, suspended sediments, coliforms, metals, periphyton, and benthic invertebrates, and will be a designated as a future water quality objectives monitoring site. The province has also monitored Round Lake, Tyhee Lake, Lake Kathlyn, and

Seymour Lake since 1885 for coliforms, turbidity, nutrients including total phosphorus, color, metals.
Biomonitoring – There are 26 biomonitoring sites located in the Bulkley watershed (excluding Morice and Upper Bulkley sub-basins). Locations include; Station Cr., Kwun Cr., Causqua Cr., Cory Cr., Gramophone Cr., Toboggan Cr., Reiseter Cr., Glacier Gulch Cr., Kathlyn Cr., Bulkley R., Chicken Cr., Canyon Cr., Driftwood Cr., Pine Cr., Sinclair Cr., Arnett Cr., Jonas Cr., Howson Cr., Goathorn Cr., Deep Cr., and Thompson Cr. 24 of these sites include intermittent climate, hydrology, landscape, physical, substrate, and water quality (metals, nutrients, pH, DO, TSS, temp, etc.) data.

Pressure Monitoring – Data available from the NWBC development monitoring include; clear cuts, roads, mining, power line, rail line, pipeline, wind power, and water license layers.

Upper Bulkley

Water Quality & Quantity Monitoring – Environment Canada has operated a hydrometric station on Buck Cr. since 1973. Discontinued hydrometric stations include; Richfield Cr. 1964 – 1974, Foxy Cr. 1974 – 1975, Lu Cr. 1974 -1975, Maxan Cr. above Bulkley Lk. 1974 -1979, and Maxan Cr. at outlet of Maxan Lk. 1974 – 1976. DFO collected water temperature data from the Upper Bulkley River from 1994 – 1999, and from Crow Cr., Maxan Cr., Buck Cr., and the Upper Bulkley River (near Topley) from 2000 – 2005.

Biomonitoring – There are 7 biomonitoring sites in the Upper Bulkley watershed, including; Upper Bulkley R., Buck Cr., Bob Cr., Foxy Cr., McQuarrie Cr., Byman Cr., and Richfield Cr. All sites include intermittent climate, hydrology, landscape, physical, substrate, and water quality (metals, nutrients, pH, DO, TSS, temp, etc.) data.

Pressure Monitoring – The BC Ministry of Environment monitors the closed Equity Silver Mine (Foxy and Buck Cr., and Goosly Lk.) for metals, total suspended solids, sulphate, and benthic invertebrates. This information is used to assess the downstream effects of metal acid mine drainage, and metal leaching impacts in the watershed (Tamblyn pers comm). Data available from the NWBC development monitoring include; clear cuts, roads, mining, power line, rail line, pipeline, wind power, and water license layers.

Morice

Water Quality & Quantity Monitoring – Environment Canada operates three hydrometric stations in the Morice watershed on the Nanika River, Morice River (at outlet of Morice Lk.), and Thautil Cr. One discontinued station operated at the mouth of the Morice River during 1971. DFO collected water temperature data from Owen Cr, Gosnell R., McBride Cr., Bustards Pond, and two sites on the Morice R. from 1994 -1999, and on Shannon Cr. from 2000 – 2005.

Biomonitoring – There are 17 biomonitoring sites in the Morice watershed. Sites include; Berg Far Field Cr., Kidprice Cr., Redslide Cr., McBride Cr., Nado Cr., Pimpernell Cr.,

Lamprey Cr., Gosnell Cr., Lamprey Cr., Shea Cr., Crystal Cr., Chicken Cr., Llojuh Cr., Raina Cr., Deny's Cr., and Owen Cr. All sites include intermittent climate, hydrology, landscape, physical, substrate, and water quality (metals, nutrients, pH, DO, TSS, temp, etc.) data.

Pressure Monitoring – Data available from the NWBC development monitoring include; clear cuts, roads, mining, power line, pipeline, wind power, and water license layers. The Morice watershed will be a focus area for the Northwest BC cumulative effects project currently underway by the Bulkley Valley Research Centre. This project should produce data relevant for all of the recommended pressure indicators.

Apendix B. Skeena Salmon Habitat Monitoring - Suggested Indicators, Metrics, Benchmarks, and Data Sources

Indicator	Suggested Metric	Suggested Impact Benchmark	Data Type	Name of Data Set	Custodian	Comments
Pressure (Stressor) Indicators						
Total Land Alteration	Total percent land cover alteration	Develop rankings based on benchmark assessment for combined metrics				
	Equivalent Clearcut Area	Functioning: less than 15% ECA with no concentration of disturbance in unstable areas. At-Risk: less than 15% ECA with concentration of disturbance in unstable or potentially unstable areas. Non-functional: > 15% ECA and disturbance concentrated in unstable or potentialy unstable areas.	Cut Blocks	FTEN Cut blocks	BC Gov't	2009 Kalum Stream Bioassessment report contain ECA and road density analysis for 30 small and medium watesheds within the Kalum, Lakelse, Zymoetz, Mid Skeena, Kitwanga and Kispiox sub basins
			Silviculture Openings	RESULTS openings	BC Gov't	
	Peak Flow Index *	?	*Elevation (required if ECA is used to calculate peak flow index for subwatersheds)*	*TRIM DEM (1:20,000)*	*BC Gov't*	*May need to negotiate licensing arrangements. Also possible to use the Federal 1:50,000 DEM which is free.*
	Extent of Agricultural activity	TBD	Private land outside of municipalities.	TANTALIS	BC Gov't	This data set would be a surrogate. It is unknown whether a dataset exists that clearly identifies agricultural activities. Determining private land spatially is very time consuming as there is no comprehensive dataset.
			Agricultural Land Reserve	ALR	BC Gov't/Regional District	Verify the extent to which the ALR represents present agricultural activities.

Adapted from: Pfals, 2011; Stalhberg et al, 2009

Apendix B. Skeena Salmon Habitat Monitoring - Suggested Indicators, Metrics, Benchmarks, and Data Sources

Indicator	Suggested Metric	Suggested Impact Benchmark	Data Type	Name of Data Set	Custodian	Comments
			Range Land	Range Tenure; Range Pasture	BC Gov't	Grazing and hay cutting licence and permits (crown land)
	Riparian Disturbance - Agricultural	5% Rparian disturbance = point of concern.	No existing dataset	none		No dataset available
	Riparian Disturbance - Forestry	5% Rparian disturbance = point of concern.	Forest Cover Reserves	RESULTS		Spatial representation of reserves (riparian, WTP, other). Reasonably current but can be quite detailed.
	Linear Developments	TBD	Rail, pipelines, powerlines	NWBC-SEAK	SkeenaWild/ HI/RWB	Data is current to November 2011. No update cycle currently in place.
Classifying current remote sensinimagery to capture land cover alteration instead of relying on vector data, should be investigated for this indicator.						

Adapted from: Pfals, 2011; Stalhberg et al, 2009

Apendix B. Skeena Salmon Habitat Monitoring - Suggested Indicators, Metrics, Benchmarks, and Data Sources

Indicator	Suggested Metric	Suggested Impact Benchmark	Data Type	Name of Data Set	Custodian	Comments
Watershed Road Development	*Road Density*	*<.4 km per km2 = lower risk. >.4km per km2 = higher risk*	*Roads*	*FTEN roads*	*BC Gov't*	*Only records Forest Tenure road permits. Currency is reasonable but dataset may have some backlog. 2009 Kalum Stream Bioassessment report contains ECA and road density analysis for 30 small and medium watesheds within the Kalum, Lakelse, Zymoetz, Mid Skeena, Kitwanga and Kispiox sub basins*
				TRIM roads	*BC Gov't*	*1:20,000 scale, no update cycle.*
				Mining roads - NWBC-SEAK	*SW/HI/RWB*	*Current to Nov 2011. No update cycle in place.*
It is fairly straightforward to put together a reasonable dataset that represents the presence of resource based roads for the Skeena watershed. To obtain further descriptive information for each road, such as status (active, deactivated), access level (2WD, 4WD, ATV), purpose (forestry, mining) or date of construction is time consuming (expensive).						
BC Gov't is currently developing a Resource Roads Act, which will pull all the various resource roads together (except mining). 3						
			Geology	Bedrock Geology and Faults	BC Geological Survey	Compiled at 1:100,000 scale
			Slope	TRIM DEM	BC Gov't	Slope can be derived from DEM. May need to negotiate licensing arrangements. Also possible to use the Federal 1:50,000 DEM which is free.
			Terrain	*Terrain Inventory Mapping (TIM)*	*BC Gov't*	*Verify extent of coverage as well as currency.*
			Precipitation	Climate Data	Environment Canada	Gauge sites are limited across Skeena Watershed.4
Riparian Disturbance	Riparian within 30 m of bank	5% Rparian disturbance = point of concern.	Baseline Thematic Mapping (BTM)	BC Watershed Statistics	BC Gov't	I don't see riparian within this database. Also, imagery used for the BTM is from 1998-2001. I suspect this dataset may be quite out of date.

Adapted from: Pfals, 2011; Stalhberg et al, 2009

Apendix B. Skeena Salmon Habitat Monitoring - Suggested Indicators, Metrics, Benchmarks, and Data Sources

Indicator	Suggested Metric	Suggested Impact Benchmark	Data Type	Name of Data Set	Custodian	Comments
			Forest Cover Reserves	RESULTS		Spatial representation of reserves (riparian, WTP, other). Reasonably current but can be quite detailed.
See riparian section under total land disturbance. I suspect agricultural riparian areas are not recorded within any spatial dataset.						
Water Extraction		TBD: Water extraction should not compromise minimum instream flow needs, or impeed fish passage.	In-stream flow levels	Water license sites	BC Gov't	Data available through the NWBC-SEAK project.
						Has max allocation information with data.
			Obstructions	Various projects		The Upper Bulkley has been assessed fairly extensively through a variety of projects. Detailed obstruction information is most likely available but may not be in a digital spatial file.
Permitted Waste Management Discharges	Concentration of contaminants, nutrients, disolved oxygen, temperature, disharge; Invertibrate presence and abundance in relation to invertibrate status at reference site; Etc.	TBD: Permitted waste discharge should fall within provincial guidelines, should not exceed levels where fish are determined to be at risk (metal concentrations, acid, nutrient loading). Site specifc guidlines may be available. Cumulative impacts from multiple discharge sites needs to be considered.	Mining Discharge: Water Quality (metals, total suspended solids, sulphate, nitrate, nitrite). Periodic environmental effects monitoring (Sediment quality, fish health and metals in fish tissue, benthic invertebrates, water quality).	BC Provincial waste (under conversion); CABIN	BC Gov't - MOE Environmental protection division; Environment Canada CABIN	Mine Monitoring programs change over time depending on permit requirements and environmental effects monitoring programs.

Adapted from: Pfals, 2011; Stalhberg et al, 2009

Apendix B. Skeena Salmon Habitat Monitoring - Suggested Indicators, Metrics, Benchmarks, and Data Sources

Indicator	Suggested Metric	Suggested Impact Benchmark	Data Type	Name of Data Set	Custodian	Comments
	Concentration of contaminants, nutrients, disolved oxygen, temperature, disharge	TBD	Municipal Discharge: Water Quality	BC Provincial waste (under conversion)	BC Gov't - MOE Environmental protection division	There are currently 12 municipal disharge sites in the Skeena. Environmental effects depend on level of treatment, volume and dilution. Winter low flow present the greatest potential risks to fish due to decreased dilution rates, and potential for fish holding due to higher relative temperature at discharge sites.
State (Impact) & Quantity Indicators						
Water Quality	Concentration of contaminants, nutrients, disolved oxygen	TBD: benchmarks could align with provincial water quality standards. Specific tolerances for salmonids should be considered.	Water Quality (metals, total suspended solids, sulphate, nitrate, nitrite)	HYDAT, BC provincial waste, CABIN, Individual FN's data sets	BC Gov't, Environment Canada,Water Survey of Canada, Skeena Fisheries Commission, Gitxsan Watershed Authority, Gitanyow Fisheries, Tahltan Fisheries	Water quality information is typically collected for specific purposes such as waste disharge, or is collected oportunistically in conjunction with benthic invertibrate monitoring, and fisheries monitoring.

Adapted from: Pfals, 2011; Stalhberg et al, 2009

Apendix B. Skeena Salmon Habitat Monitoring - Suggested Indicators, Metrics, Benchmarks, and Data Sources

Indicator	Suggested Metric	Suggested Impact Benchmark	Data Type	Name of Data Set	Custodian	Comments
Water Temperature	Temperatures relevant to juvenile coho rearing, and temperatures relevant to migration conditions for all salmo species	Upper Optimum Temperature Range UOTR = 15 degrees C; Impairment Temperature IT = 20 degrees C	Temperature degrees C	HYDAT, BC provincial waste, CABIN, Individual FN's data sets	BC Gov't, Environment Canada,Water Survey of Canada, Skeena Fisheries Commission, Gitxsan Watershed Authority, Gitanyow Fisheries, Tahltan Fisheries	
Stream Discharge	m3 during Aug / Sept	Discharge (m3) less than 20% natural mean annual discharge during July / Sept	Volume m3	HYDAT, Individual FN's data sets	Water Survey of Canada, Skeena Fisheries Commission, Gitxsan Watershed Authority, Gitanyow Fisheries, Tahltan Fisheries	Water level information may only be available for some sites. Impact benchmark should consider fish passage needs, and may need to be site specific

Adapted from: Pfals, 2011; Stalhberg et al, 2009

Apendix B. Skeena Salmon Habitat Monitoring - Suggested Indicators, Metrics, Benchmarks, and Data Sources

Indicator	Suggested Metric	Suggested Impact Benchmark	Data Type	Name of Data Set	Custodian	Comments
Suspended Sediment	Total suspended sediments (mg/l, ppm)	25 mg/l in 24hrs when bakcground is less than or equal to 25; Mean of 5 mg/l in 30 days when background is less than or equal to 25; 25 mg/l when background is between 25 and 250; 10% when background is greater than 250	mg/l or ppm	HYDAT, CABIN, BC Provincial Waste, Individual FN's data sets	BC Gov't, Environment Canada,Water Survey of Canada, Skeena Fisheries Commission, Gitxsan Watershed Authority, Gitanyow Fisheries, Tahltan Fisheries	There is potential to develop a correlation curve of turbidity to TSS.
Accessible Stream Length	Kilometers	NA	Salmon spawning/presence	BC FISS, BC FIQD, Salmon data (spawning and presence)	BC Gov't, Skeena Wild, Ecotrust Canada	Salmon spawning and presence identified and tied to stream name.
			Stream crossing database	PSCIS Assessments	BC Gov't	Need to examine this dataset further for suitability.
Key Spawning Areas	Total length (km) of spawning area per watershed & CU	NA	Salmon spawning/presence	BC FISS, Salmon data (spawning and presence)	BC Gov't, SkeenaWild	Salmon spawning and presence identified and tied to stream name.
Lake Productive Capacity	Photosynthetic Rate Model	No specific benchmarks currently exist. This information could be compared against the estimated natural range of lake productivity for a specific lake, and trends can be monitored over time	Sockeye Lake Rearing Capacity	Cox-Rogers, S., Hume, J., Shortreed, K., Spilsted, B., (2010). A Risk Assessment Model for Skeena River Sockeye Salmon. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2920.	DFO North Coast	Productive capacity is modeled for 29 Skeena sockeye rearing lakes

Adapted from: Pfals, 2011; Stalhberg et al, 2009

Apendix B. Skeena Salmon Habitat Monitoring - Suggested Indicators, Metrics, Benchmarks, and Data Sources

Indicator	Suggested Metric	Suggested Impact Benchmark	Data Type	Name of Data Set	Custodian	Comments
Coldwater Refuge Zone	Width (m) as measured through disolved oxygen and temperature profiles	Develop distribution curve of width of all Skeena sockeye lakes coldwater refuge zones and rank low, med, and high risk	Temp & DO profiles	DFO limnological reports, Individual FN's data sets	DFO, Skeena Fisheries Commission, Gitxsan Watershed Authority, Gitanyow Fisheries Authroity	Requires collation of DO and temp profile information from a variety of limnological reports and FN's data sets
Lake shore Spawning Areas	Total length of lake shore spawning area per watershed and CU	NA	Salmon spawning/presence	Salmon data (spawning and presence), EcoTrust Canada SWI Project	DFO, SkeenaWild, Ecotrust Canada, Gitanyow Fisheries Authority	Locations may be covered off to some extent in the Salmon data prepared by SkeenaWild, and Ecotrust Canada. It is uncertain how much detailed mapping / measurement exist for lake shore spawning areas in the Skeena
Benthic Invertebrates	Invertebrate presence and abundance in relation to invertibrate status at reference site	Use reference site probability elipses to categorize into; Reference Condiiton, Slightly Stressed, Stressed, or Severely Stressed	Invertebrate taxonomy and abundance	CABIN	Environment Canada	Over 200 sites in the Skeena. This data base also contains water quality, and physical habitat data. 2009 Kalum Stream Bioassessment report contains ECA and road density analysis by watershed (agricultural, mining, and forest fire disturbance also analyzed with no impacts found in these watershed)
Pressure (Stressor) Indicators						
Threats - Industrial Development			Mining Tenures	NWBC-SEAK	SkeenaWild/ HI/RWB	Existing and Proposed, current to Nov 2011, no update cycle planned
			Mines	NWBC-SEAK	SkeenaWild/ HI/RWB	Existing and Proposed, current to Nov 2011, no update cycle planned
			Pipelines	NWBC-SEAK	SkeenaWild/ HI/RWB	Existing and Proposed, current to Nov 2011, no update cycle planned

Adapted from: Pfals, 2011; Stalhberg et al, 2009

Apendix B. Skeena Salmon Habitat Monitoring - Suggested Indicators, Metrics, Benchmarks, and Data Sources

Indicator	Suggested Metric	Suggested Impact Benchmark	Data Type	Name of Data Set	Custodian	Comments
			Transmission Lines	NWBC-SEAK	SkeenaWild/ HI/RWB	Existing and Proposed, current to Nov 2011, no update cycle planned
			Hydro Projects	NWBC-SEAK	SkeenaWild/ HI/RWB	Existing and Proposed, current to Nov 2011, no update cycle planned
			Harvested Areas	FTEN Cut blocks	BC Gov't	Data entry may be backlogged - check currency of data. Data contains proposed
Analysis of salmon habitat impacts from current and proposed debvelopments should be undertaken utilizing a combination of pressure, state, and quatity indicators suggested above.						
Threats - Climate Change			Mountain Pine Beetle Infestation	Forest Health Data	BC Gov't	Yearly surveys of pest infestation areas
			Stream flow and temperature		University of Montana / University of Washington	Hydrological modelling for Skeena Watershed to 2108
			Forest Cover		UBC	Forest Cover modelling to 2090 for Kalum Forest District
Cumulative Impacts Assessment	Under development	under development	Various, including many suggested above	Under development	Bulkley Valley Research Centre	Scheduled to be complete Nov 2013. Development scenarios will provide insight into current and future impacts on salmon from forestry, mining, agriculture, linear developments, and climate change.
Groundwater Exploitation	TBD, potentially volume (m3) extracted, water quality effects	TBD, should be related to in-strem flow needs, and water quality requirments	Unavailable	Unavailable		Unknow whether data on groundwater currently exists for the Skeena watershed. Baseline data requirements, metrics and benchmarks should be developed for specific projects with potentially significant groundwater impacts

Adapted from: Pfals, 2011; Stalhberg et al, 2009

Apendix B. Skeena Salmon Habitat Monitoring - Suggested Indicators, Metrics, Benchmarks, and Data Sources

Indicator	Suggested Metric	Suggested Impact Benchmark	Data Type	Name of Data Set	Custodian	Comments
1. Community Watershed Guidebook. Ministry of Forests. http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/watrshed/watertoc.htm						
2. Riparian Management Area Guidebook. Ministry of Forests. http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/riparian/Ripar2.htm#link53						
3. Proposed Natural Resource Roads Act. http://www.for.gov.bc.ca/mof/nrra/index.htm. I have provided input to the process requesting that mining roads should						
4. Environment Canada Climate Data. http://climate.weatheroffice.gc.ca/climateData/canada_e.html						

Adapted from: Pfals, 2011; Stalhberg et al, 2009

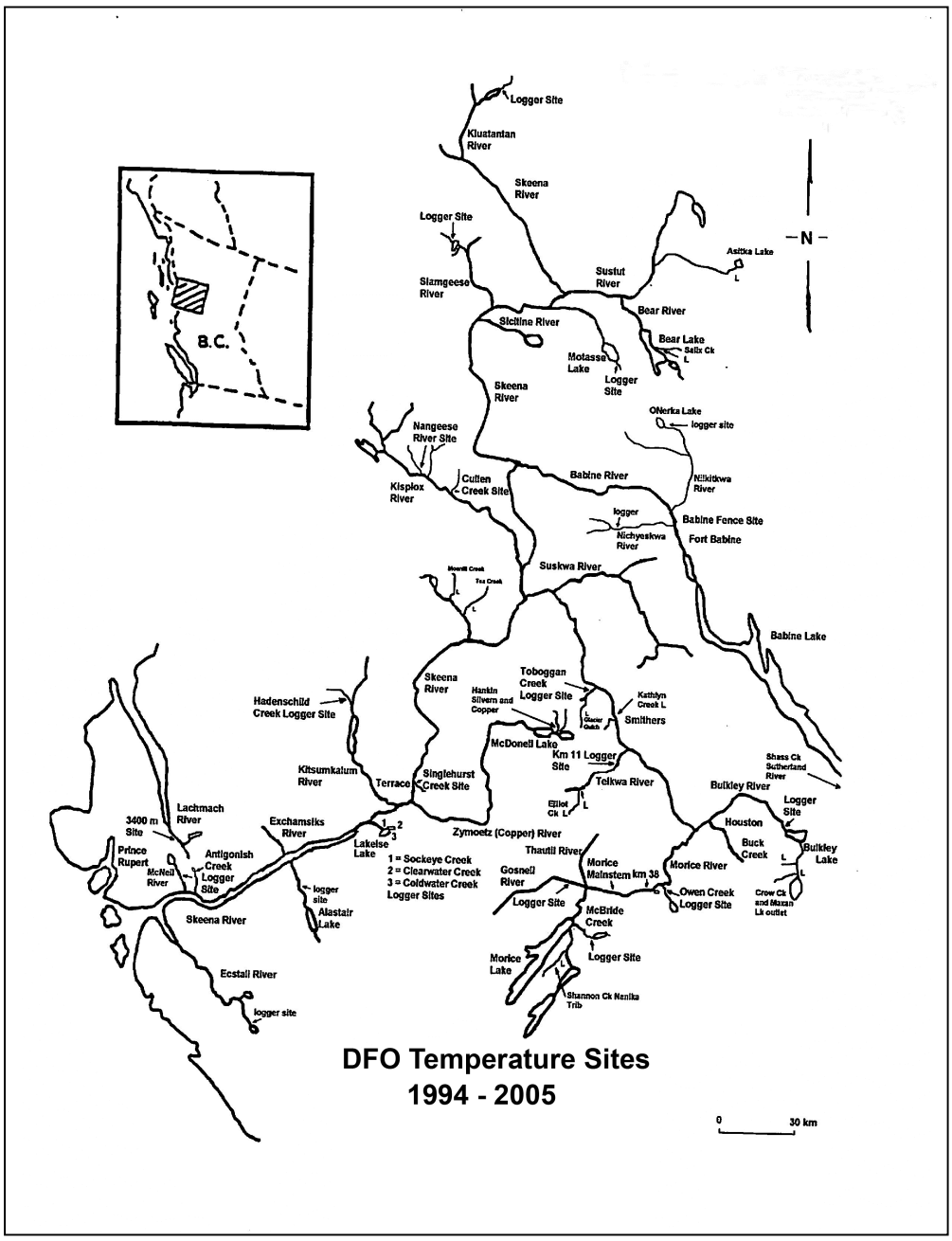
APPENDIX C – SKEENA WATER QUALITY AND QUANTITY DATA COLLECTION SITES

Skeena Hydrometric Stations Active December 2008							
Map No.	**Station No.**	**Location**	**Year From**	**Year To**	**Sed Data**	**RHBN[1]**	**Real Time[2]**
2	08EB003	Skeena River at Glen Vowell, BC,	1960	2012	N	N	Y
3	08EB004	Kispiox river near Hazelton, BC	1963	2012	N	N	Y
4	08EB005	Skeena River above Babine River, BC	1970	2012	N	N	Y
	08EB006	Compass Creek near Kispiox, BC	1997	2012	N	N	N
6	08EC001	Babine River at Babine, BC	1929	2012	N	N	Y
7	08EC003	Babine Lake at Topley Landing, BC	1955	2012	N	N	Y
	08EC004	Pinkut Creek near Tintagel, BC	1929	2012	N	N	N
5	08EC013	Babine River at Outlet of Nilkitkwa Lake, BC	1972	2012	N	N	Y
	08EC014	Twain Creek tributary near Babine Lake, BC	1997	2012	N	N	N
11	08ED001	Nanika River at outlet of Kidprice Lake, BC	1950	2012	N	Y	Y
12	08ED002	Morice River near Houston, BC	1929	2012	N	N	Y
	08ED004	Thautil Corner Creek near Morice Lake, BC	1997	2012	N	N	N
	08EE003	Bulkley River near Houston, BC	1930	2012	N	N	N
10	08EE004	Bulkley River at Quick, BC	1930	2012	Y	N	Y
	08EE008	Goathorn Creek near Telkwa, BC	1960	2012	N	N	N
	08EE012	Simpson Creek at the mouth, BC	1969	2012	N	N	Y
	08EE013	Buck Creek at the mouth, BC	1973	2012	N	N	N
13	08EE020	Telkwa River below Tsai Creek, BC	1975	2012	N	N	Y
	08EE025	Two Mile Creek in District Lot 4834, BC	1982	2012	N	N	N
1	08EF001	Skeena River at Usk, BC	1928	2012	Y	N	Y
	08EF005	Zymoetz River above O.K. Creek, BC	1963	2012	N	N	N
	08EF006	M3 Creek near Smithers, BC	1997	2012	N	N	N
	08EG012	Exchamsiks River near Terrace, BC	1962	2012	N	N	N
	08EG017	Deep Creek above reservoir, BC	1992	2012	N	N	N
	08EG018	Egan Creek near Rosswood, BC	1997	2012	N	N	N
1. Reference Hydrometric Basin Network (RHBN)							
2. Real time data is available on the Internet at: http://scitech.pyr.ec.gc.ca/waterweb/formNav.asp							

Active hydrometric stations in the Skeena Basin (Environment Canada, 2011b)

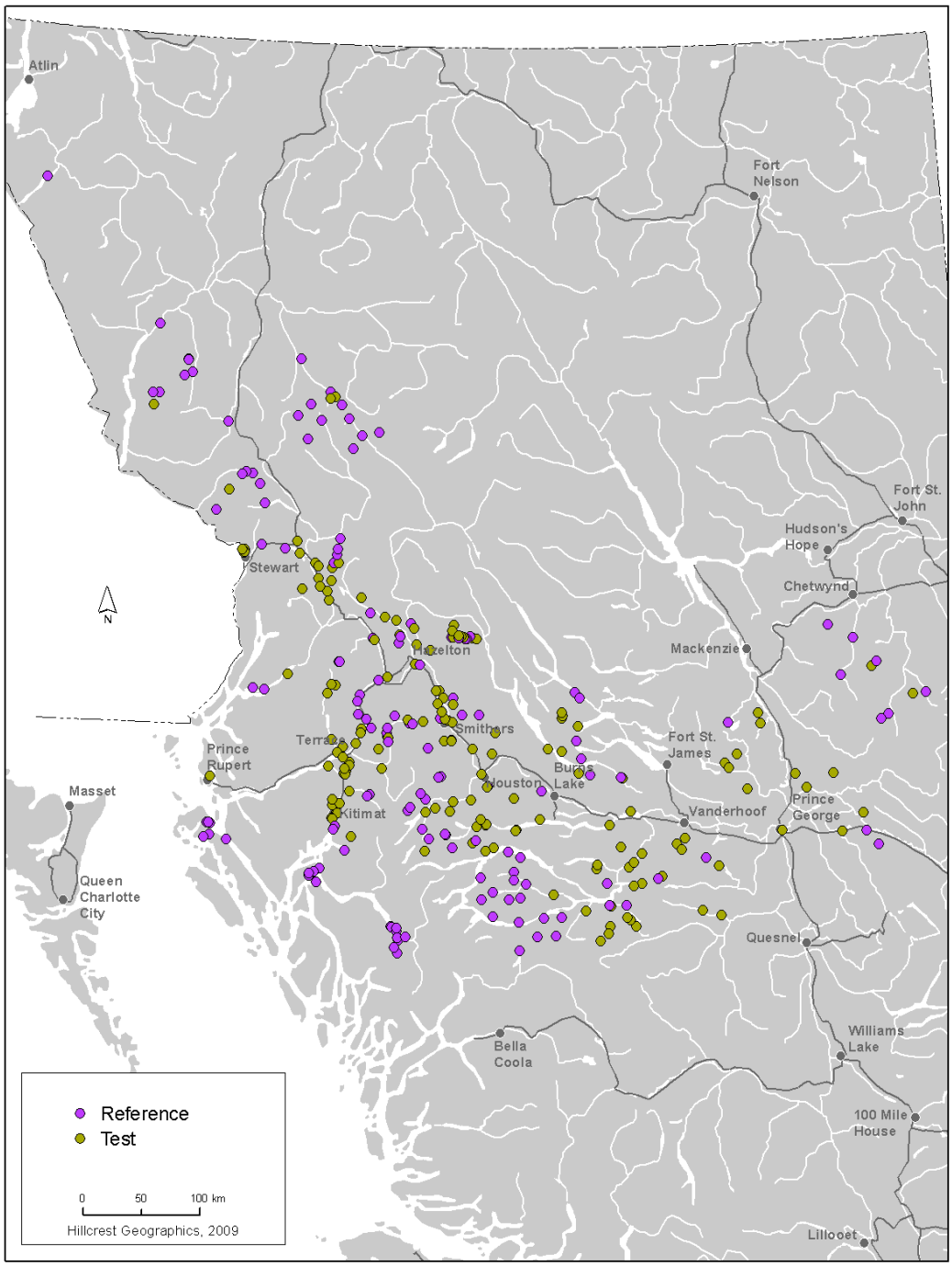
Discontinued Skeena Basin Hydrometric Stations			
Station No.	**Location**	**Year From**	**Year To**
08EC002	FULTON RIVER AT THE MOUTH, BC	1963	1970
08EC005	FULTON RIVER AT FULTON LAKE NARROWS, BC	1960	1963
08EC006	CHAPMAN LAKE NEAR SMITHERS, BC	1967	1970
08EC007	FULTON LAKE NEAR SMITHERS, BC	1964	1973
08EC008	MORRISON RIVER AT OUTLET OF MORRISON LAKE, BC	1965	1970
08EC009	FULTON RIVER AT OUTLET OF CHAPMAN LAKE, BC	1967	1970
08EC011	BABINE LAKE AT SMITHERS LANDING, BC	1972	1977
08EC012	BABINE LAKE AT PENDLETON BAY, BC	1972	1976
08ED003	MORICE RIVER AT THE MOUTH, BC	1971	1971
08EE001	BULKLEY RIVER NEAR HAZELTON, BC	1915	1952
08EE005	BULKLEY RIVER NEAR SMITHERS, BC	1915	1971
08EE009	RICHFIELD CREEK NEAR TOPLEY, BC	1964	1974
08EE010	KATHLYN CREEK ABOVE SIMPSON CREEK, BC	1967	1979
08EE011	KATHLYN LAKE NEAR SMITHERS, BC	1968	1980
08EE014	CANYON CREEK NEAR SMITHERS, BC	1973	1998
08EE015	FOXY CREEK ABOVE LU CREEK, BC	1974	1975
08EE016	LU CREEK NEAR THE MOUTH, BC	1974	1975
08EE018	MAXAN CREEK ABOVE BULKLEY LAKE, BC	1974	1979
08EE019	MAXAN CREEK AT OUTLET OF MAXAN LAKE, BC	1974	1976
08EE028	STATION CREEK ABOVE DIVERSIONS, BC	1985	1998
08EF003	ZYMOETZ RIVER NEAR TERRACE, BC	1951	1964
08EF004	KITSEGUECLA RIVER NEAR SKEENA CROSSING, BC	1960	1971
08EG006	KITSUMKALUM RIVER NEAR TERRACE, BC	1928	1952
08EG007	LAKELSE RIVER NEAR TERRACE, BC	1948	1955
08EG008	WILLIAMS CREEK NEAR TERRACE, BC	1948	1954
08EG010	SCHULBUCKHAND CREEK NEAR TERRACE, BC	1953	1955
08EG011	ZYMAGOTITZ RIVER NEAR TERRACE, BC	1960	1995

Discontinued hydrometric stations in the Skeena Basin (Environment Canada, 2011b)



DFO Temperature Data Collection Sites 1994-2005 (Finnegan, 2011)

APPENDIX D: BIOMONITORING SITES IN NORTHWEST BC



Biomonitoring Test and Reference Sites in Northwest BC (Bennett, 2009)

APPENDIX E: THESIS PROJECT INTERVIEW QUESTIONS

1) What policies or programs are you involved in that relate to habitat monitoring? Are these specific to the Skeena?

2) What habitat monitoring indicators or tools are being used in your work / program?

3) What habitat monitoring indicators do you believe would be valuable for a Skeena habitat monitoring program?

4) What data collection standards are you currently using; do you see potential, or willingness to standardize data collection on a regional scale?

5) What specific geographic areas are you and your organization monitoring in the Skeena?

6) Are there geographic locations where you think monitoring should be prioritized?

7) Does your organization currently work with any other organizations in performing habitat monitoring work?

8) Can you think of any potential partnerships, tools, or efficiencies that would improve your habitat monitoring capacity, and or habitat monitoring capacity in the region?

9) What challenges do you face (capacity, training, etc.) in your program which relates to habitat monitoring?

10) Is your habitat monitoring program funding stable? Do you have any recommendations for accessing additional habitat monitoring resources?

11) Could (would) your program contribute to the requirements for monitoring under the WSP?

12) Do you have any ideas or recommendations on potential Salmon habitat monitoring governance structures for the watershed?

13) Do you have any other general suggestions on how to increase monitoring capacity in the Skeena Watershed?

14) Can you provide any supporting information on your organizations habitat monitoring activities or any other information which may be beneficial to this thesis project?

15) Do you have any suggestions of other professionals who may have pertinent information on habitat monitoring?

APPENDIX F: SKEENA SALMON AND HABITAT DIVERSITY BY SPECIES

Sockeye salmon use thirty lake systems in the Skeena for juvenile rearing and lakeshore spawning. Tributaries and outlets of these lakes are the major spawning areas. There are also two river-type sockeye populations, which are lesser known, spawning in the Skeena River and several tributaries (Ecotrust Canada, 2011). They spend most of the juvenile portion of their life cycle in the lower river back channels, estuary, and near-shore marine environments. Combined, there are 32 sockeye Conservation Units (biologically distinct populations classified under the Federal Wild Salmon Policy). Today, approximately 90% of Skeena sockeye are produced in the Babine system (BC's largest natural lake), although historically non-Babine systems accounted for a larger portion of the total Skeena sockeye production (approximately 30 - 40%). This decline is mainly attributed to overharvesting and some localized habitat issues (Wood, 2001). Overall Skeena sockeye habitat remains in good health and many Conservation Units (CU's) exist in pristine areas of the watershed.

Chinook are known to spawn in 85 Skeena tributaries, using relatively fast flowing areas with large gravel. Lake outlets, and the main-stems of larger tributaries, are the main spawning areas, with the Kalum, Bear, and Morice systems contributing 65 – 75% of the known Chinook production (Gottesfeld & Rabnett, 2008). Other less understood areas, such as the Skeena main-stem below Terrace and the upper Skeena, are also thought to contribute significant numbers. Side channels and gravel bars along the middle and lower Skeena are important habitats for juveniles, contributing substantially to the productive capacity of the system as a whole. The delineation of Chinook CU's is provisionally set at twelve (Morrell, 2010). Overall,

Chinook habitat appears to be fairly healthy, although logging and agriculture have had significant localized impacts, especially in some of the smaller tributaries like the Upper Bulkley and Lakelse (Gottesfeld & Rabnett, 2008).

Coho salmon are the most widespread, occupying hundreds of small and medium-sized tributaries throughout the Skeena. They are reliant on countless off-channels and small tributaries for the juvenile portion of their life cycle. There are currently four Skeena coho CU's, with a highly diverse number of spawning and rearing locations in each (Holtby & Ciruna, 2007). Historically, coho suffered high harvest levels and habitat destruction from logging. In recent years harvest has been reduced and logging slowed or improved, which has helped in rebuilding (Gottesfeld & Rabnett, 2008).

Chum salmon spawn mostly in the lower Skeena and Ecstall Rivers, although some populations exist as high up as the Babine and Slamgeesh tributaries (Peacock & Spilsted, 2010). Chum are the least understood and spawning sites are difficult to assess due to turbidity in many known spawning tributaries and the lower Skeena (Gottesfeld & Rabnett, 2008). Surveys show that side channel and groundwater upwelling areas in the lower Skeena are important. After hatching in the spring, chum remain only a few weeks in freshwater, spending most of their juvenile life in the Skeena estuary and near shore marine environments. Three CU's have been defined by DFO (Holtby & Ciruna, 2007) and in general habitat is thought to be fairly good, although some areas in the lower Skeena have been impacted by highway and railway development (Gottesfeld & Rabnett, 2008).

Pink salmon exist in large numbers throughout most of the watershed, with abundance generally increasing as you get closer to the sea. Several tributaries have high value pink habitat, including the Lakesle, Kitwanga, Kispiox, Babine, and Morice rivers (Gottesfeld & Rabnett, 2008). Similar to chum, pinks migrate quickly to the estuary and near shore marine areas after they hatch out of the gravel each spring, making these areas critical to their life history. Three CU's have been delineated, and their habitat appears to be healthy in most of the watershed at this time (Holtby & Ciruna, 2007; Gottesfeld & Rabnett, 2008).

Steelhead are a rainbow trout with an anadromous lifecycle similar to Pacific salmon, and are officially classified as salmon. The Skeena is possibly the most diverse steelhead system in the world, with the majority of low gradient tributaries near and above Terrace containing summer-run steelhead, and nearly all of the low gradient tributaries in the watershed near and below Terrace containing winter-run steelhead (Gottesfeld & Rabnett, 2008; MOE, 2010; Tautz et al., 2011). Several have a combination of the two life history types (MOE, 2010). Due to their long residence in fresh water and use of small tributaries for spawning, steelhead are particularly susceptible to habitat disturbance. CU's for steelhead are provisionally set at 11, and the majority of their habitats remain healthy with some localized impacts from logging, agriculture, and linear developments (Tautz et al., 2011; Gottesfeld & Rabnett, 2008).